# RETHINKING TEACHER PREPARATION: CONCEPTUALIZING SKILLS AND KNOWLEDGE OF NOVICE TEACHERS OF SECONDARY MATHEMATICS

by

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This dissertation has been read by each member of the following supervisory committee and by majority vote has been found to be satisfactory.

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I have read the dissertation of Margarita Borelli Cummings in its final form and have found that (1) its format, citations, and bibliographic style are consistent and acceptable; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the supervisory committee and is ready for submission to The Graduate School.

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## ABSTRACT

This dissertation examines the extent to which novice secondary mathematics teachers (licensed and currently teaching in Utah) perceive they are prepared to do the work of teaching secondary mathematics. It first examined if novice secondary mathematics teachers' perceptions of their knowledge and skills of doing their work fell into four conceptualized domains: pedagogical knowledge, mathematical knowledge, pedagogical content knowledge, and curricular knowledge. Then it examined the extent to which novice teachers felt prepared do their work and where they perceived they gained their skills (in college or outside of college). Finally, it examined if novice teachers from different preparation programs in Utah reported a difference in their perceptions of preparedness. An exploratory factor analysis of the survey instrument used for the research indicated that novice teacher perceptions of their knowledge and skills did indeed fall into the four conceptualized domains. Analysis of the data also revealed that novice teachers felt most prepared in the domain of mathematical knowledge and least in the domain of pedagogical knowledge, with their perceptions of preparedness in the domains of pedagogical content knowledge and curricular knowledge between mathematical and pedagogical knowledge. Teachers also reported that they gained their mathematical and pedagogical knowledge both in and out of college, but that they gained their pedagogical content knowledge and curricular knowledge primarily outside of college. Novice teachers in the sample did not report a difference in their perceptions of preparedness in any of the domains by institution in which they were prepared. Findings from the study point to a need to rethink teacher preparation in secondary mathematics.

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# CHAPTER 1

# A FRAMEWORK FOR THINKING ABOUT SECONDARY MATHEMATICS TEACHER PREPARATION

At my very first parent teacher conference, the parent of one of my Algebra students leaned over the desk between us and quietly confessed, "I never really understood math." She proceeded to tell me that she had wanted to be a doctor, but could not get past her early college mathematics classes. Instead, she went into law. I was floored. Clearly, she was intelligent and studious. After all, she made it through law school. Had she "never really understood math," and how could math have stood in the way of her pursuing her dream? She did not blame any one thing in her education, other than to say that none of her secondary mathematics teachers could help her understand *why* the *rules* worked. She said she liked that math always consistently followed clear rules, but she did not understand the reasons for the rules, and thus could not remember when or how to apply the rules. For her, math was a mystery. In the 14 years I taught secondary mathematics, not a year went by without a similar story.

When I became the director of math and science education for my school district, I made it my mission to ensure that all students would have high quality mathematics instruction—instruction that focused on both procedures *and* concepts so that students leaving our district would not have similar experiences. As part of that mission, we provided professional development classes for in-service teachers around mathematics pedagogy. Two things quickly became apparent to me. First, teachers were very eager to learn both the mathematics they were teaching and how to teach it; and second, there were always new teachers. It did not seem to matter how many new teachers we trained one year; the following year, there were always just as many new teachers.

All this made me wonder about mathematics teacher preparation. I knew that, for the most part, all mathematics teachers had similar preparation in terms of coursework. Further, I knew that somewhere along the line, someone or some group had determined the minimum coursework qualifications for teaching mathematics and that there was reason for the minimum coursework. What seemed unclear was whether new teachers felt that their coursework prepared them to do the work of teaching. In other words, did new teachers feel that their college coursework prepared them to teach students so that students would understand mathematics? Where did they perceive they gained the skills and knowledge of teaching mathematics?

## Statement of the Problem

During the early 1960s through the early 1980s, teacher education was primarily defined as a training problem (Cochran-Smith & Fries, 2005), but has since become "defined as a learning problem—understanding how prospective teachers learn the knowledge, skills, and dispositions needed to function as school professionals" (Cochran-Smith, 2005, p. 4). Typically, the knowledge and skills needed for teaching is defined as falling into two intertwined domains, content and pedagogy. Content and pedagogical knowledge have also been central to the question of "teacher quality" (Cochran-Smith, 2001; Darling-Hamond, 2000a, Darling-Hammond & Youngs, 2002; Kanstoroom &

Finn, 1999; Melnick & Pullin, 2000; Wilson, Floden & Ferrini-Mundy, 2001). However, it is not completely clear what content and pedagogical knowledge are most important for teachers (Shulman, 1986). The result is that teacher preparation programs vary significantly in nature and quality across the country (Goodlad, 1990) and even within institutions (Liston & Zeichner, 1991).

We know that teacher preparation matters (Darling-Hammond & Youngs, 2002). However, there is some question as to exactly what content and pedagogical knowledge teachers need in their preparation in order to transition into the work of teaching. Defining what the knowledge and skills are is essential to improving teacher preparation in mathematics.

Teacher preparation can be examined from two separate perspectives: coursework taken or self-reported perspectives of preparedness of novice teachers. The first is an "input" perspective used by researchers such as David Monk (1994) where the researcher quantifies the amount of input (coursework) teachers take during preparation. The concern with this perspective is that it does not take into account how much the teacher learned or did not learn from the "input" course(s). On the other hand, researchers such as Darling-Hammond and Youngs (2002) have employed an "output" perspective, where teachers are asked to assess their perceptions of preparedness to execute the work of teaching. Though this perspective fits better with the notion that teacher preparation is a "learning problem," it does not ascertain if and where a prospective teacher did or did not glean the knowledge and skills associated with the work of teaching. Understanding both if novice teachers have the knowledge and skills needed to execute their work and where they gained those skills is paramount in beginning the quest to better understand how to improve teacher preparation.

## Purpose of this Study

The purpose of this dissertation is to offer evidence of how novice secondary mathematics teachers perceive their work and how they perceive their preparedness. To that end, it proposes a conceptualization of mathematics teacher preparation that better addresses the skills and knowledge novice teachers need as they begin to do the work of teaching. Further, its purpose is to examine if novice secondary mathematics teachers, licensed in Utah, perceive their preparedness to do the work of teaching secondary mathematics as falling into the proposed conceptualized. It also seeks to ascertain where novice mathematics teachers believe they gained that knowledge and those skills. This study will look at these questions from the perspective of the teachers' perceptions of preparation rather than from the perspective of the "input" into preparation.

The answers to these questions directly relate to educational policy in mathematics teachers' preparation and teacher quality. This study seeks to inform policy makers of the effectiveness of the current preparation system for mathematics teacher preparation by addressing questions such as: Is the coursework requirement for teacher licensure in mathematics resulting in teachers who feel prepared to do the work of teaching mathematics? How well prepared do novice teachers feel they are to do the work of teaching secondary mathematics? What coursework might address novice teachers' needs before they begin their work of teaching?

This dissertation proposes that explicitly addressing in teacher preparation the domains of knowledge and skills that novice teachers need as they begin their work of teaching mathematics improves teacher preparation in mathematics and increases the quality of teachers entering the classroom. In order to explicitly address the knowledge and skills novice teachers need as they enter teaching, we must first identify domains in which they fall.

## Conceptual Framework

Figure 1 represents the current structure of how teacher preparation and licensure for secondary mathematics are typically conceived. Figure 2 is a proposed model of the structure around which this study seeks to show that teacher preparation and licensure should be framed for secondary mathematics. The conceptual model this study proposes identifies four domains of knowledge and skills novice teachers need as they begin to do the work of teaching mathematics at the secondary level rather than the two that the literature generally identifies. This study is limited to investigating the validity of the conceptual framework offered and the correlations between the skills and knowledge identified in the framework and teachers' sense of preparedness. In this section, I will discuss the difference between the current structure of teacher preparation and licensure (Figure 1) and the proposed model (Figure 2). In subsequent sections, I will describe the four proposed domains of novice teacher knowledge and skills and the relationship between the proposed framework and teacher preparation and licensure.

It is important to point out that the conceptual framework offered in this study refers only to the knowledge and skills that novice teachers need as they begin their work as teachers of secondary mathematics, and therefore, it represents the knowledge and

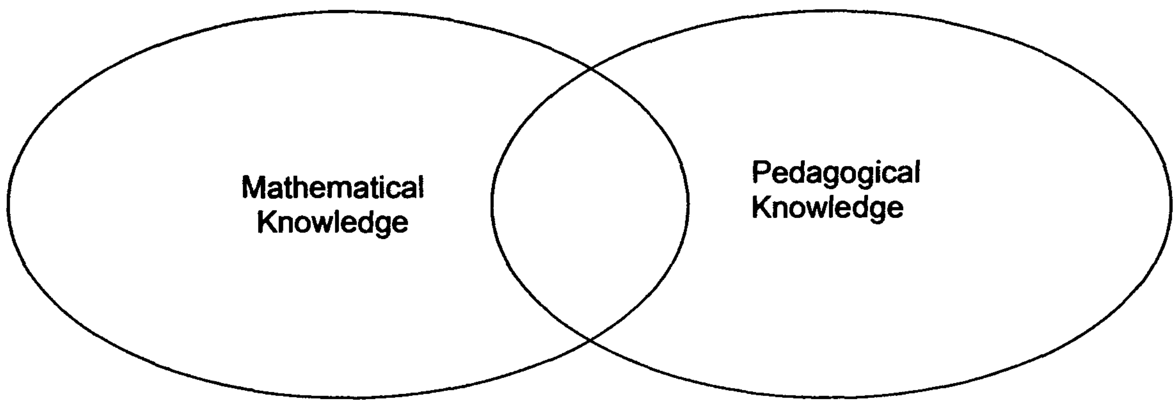


Figure 1. Current Structure of Teacher Preparation and Licensure

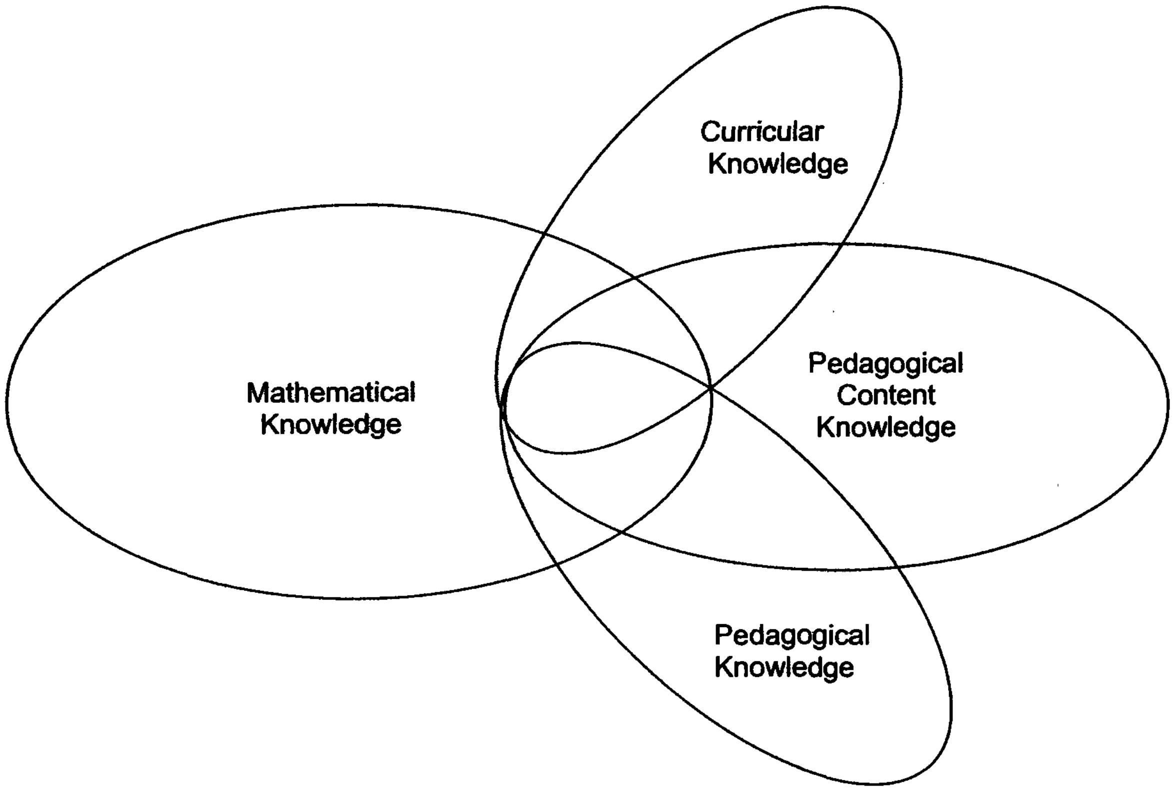


Figure 2. Conceptual Model

skills that are essential to develop during teacher preparation. In other words, I am suggesting that the four domains within the framework are the foundational knowledge and skills upon which novice teachers build to become experienced and then expert teachers. The framework does not identify the totality or full development of knowledge and skills that experienced master teachers of secondary mathematics need and use. I seek to show that the four domains in the conceptual framework are how novice teachers see their work and that novice teachers will vary in how well prepared they are in each of these domains.

As Figure 1 demonstrates, teacher preparation and licensure is typically framed around content and pedagogy. As discussed at the beginning of this chapter, content and pedagogy are the two domains central to the discussion of teacher quality and are thus essential components of preparation and licensure. I will make several arguments later in this chapter, which include why content knowledge in mathematics needs to be specifically focused on the mathematical knowledge teachers need and use; that three domains of skills and knowledge fall under the term "pedagogy" and thus need to be addressed explicitly; and by carefully defining the domains, preparation and licensure can focus more clearly on the knowledge and skills individuals must develop to do the work of teaching before they enter the classroom.

In the conceptual model proposed in this study (Figure 2), mathematical knowledge is on the left as the largest domain. Then on the right, rather than pedagogical knowledge as the sole other equal domain as is generally the structure of preparation and licensure (and as in Figure 1), I have explicated the "pedagogy" domain into three separate domains of different sizes, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge. The domains overlap to indicate two separate ideas: first, that the domains are correlated, and second, that novice teachers can and do glean some knowledge and skills in one domain as they are prepared in other domains. Also implied by the model is the notion of inward force; as teachers become more experience and skilled, the domains become more overlapped. In other words, as teachers become more experienced, their knowledge and skills become more interdependent.

## The Four Domains of Mathematics Teacher Preparation

The research literature on teacher preparation and teacher quality tends to focus on the domains of content and pedagogy—this is also the structure in which teacher preparation and licensure programs organize coursework and assessment. For individuals wishing to become mathematics teachers, this typically means taking a certain number of courses in mathematics and a certain number of courses in pedagogy and then demonstrating the knowledge learned by passing some type of examination. I will show that although the domains of "content" and "pedagogy" are vital to teacher preparation, a) content knowledge (mathematical knowledge) must be more carefully defined to explicitly identify the knowledge and skills of mathematics that secondary teachers must know and be able to do, and b) the domain of "pedagogy" should be explicated to three separate domains, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge, to better address the knowledge and skills novice teachers need as they begin their work.

Framing the Four Domains of Teacher Knowledge

The four domains that I propose fully define the knowledge and skills needed by novice teachers' as they move from "expert student to novice teacher" (Shulman, 1986, p. 8) are mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge. First, I will briefly discuss the literature around each of the four domains I am proposing. I will then explain how I am defining each domain and how each domain is independent of the others. Finally, I will discuss how I conceptualize their interplay as novice teachers do their work.

Content (Mathematical) Knowledge

Content knowledge in the literature generally refers to the *amount* of college-level subject matter studied by the teacher candidate. Typically, content knowledge is quantified by a college major, minor, or subject specific licensure. Darling-Hammond (2000b) and Wenglinsky (2002) investigated the relationship between content study and teacher effectiveness and found a positive association between the two. When specifically looking at mathematics teacher coursework (and science), Monk (1994) and Monk and King (1994) found a positive overall association between the extent of mathematics coursework taken by a teacher and student achievement. However, the results were mixed and inconsistent. They found that there were differential effects for different types of students and that the greatest positive effect was associated with the first five math classes taken by teachers. Only students at the highest level benefited from teachers who had the most content classes in mathematics; there was no effect for students at lower levels.

In other studies specific to mathematics, several researchers note that prospective teachers have difficulties explaining concepts such as the division of fractions, although they are able to apply the algorithm (Ball, 1990a; Borko et al., 1992; Ma, 1999; McDiarmid & Wilson, 1992). The general theme of these studies is that teachers are able to "do" the math they are teaching, but they do not necessarily understand the concepts that underlie the procedures or how to help students understand those concepts in a variety of ways. What begins to emerge in these and other similar studies is that there is a difference between "doing" and "understanding" mathematics and "doing" and "teaching" mathematics.

Ball, Thames, and Phelps (2008) clearly define how mathematical knowledge for teachers is different than mathematical knowledge for other fields. They explain that being able to "do" computations is necessary, but not sufficient for the teaching of mathematics. In their research, they point to a variety of explicit knowledge and skills associated with the teaching of mathematics that go beyond knowing the subject matter and are only needed for individuals who teach mathematics. For example, they note that being able to successfully carry out the algorithm for subtraction with regrouping is a skill that all need, and that that skill allows a person to recognize when an answer is correct or incorrect. However, a mathematics teacher needs to know more than how to do the computation and check if the answer is correct, she also needs to be able to identify why a student made an error (or erroneously got the right answer), help the student understand why the error is incorrect, and then help the student correct the error. Further, the teacher must be able to do all that while doing a number of other things at the same time.

We can draw two essential conclusions from the above research on "content" knowledge; first, content knowledge matters. Teachers that know their subject have students that have higher achievement. However, the correlation is strongest for the first five classes in mathematics that a teacher studies. Second, content knowledge is both generally defined by the number of courses taken in the subject (mathematics) and as specialized knowledge unique to the teaching of mathematics. The question then becomes what is the correlation between the specialized content knowledge to which Ball et al. (2008) refers and ~~the~~ college mathematics coursework, particularly the first five classes of college coursework (Monk, 1994).

## Pedagogical Knowledge

Pedagogy is also associated with student achievement. Fennema and Franke (1992) defined pedagogical knowledge as the skills used to plan lessons, structure activities, manage the classroom, motivate students, and assess content. Loughran and Russell (1997) conceptualized it as *how* a teacher teaches in conjunction with *what* one teaches. The notion that teacher pedagogical knowledge may be more important to student achievement than teacher content knowledge was advanced by Ferguson and Womack (1993). As mentioned earlier, Monk concurred suggesting that courses in methods of teaching math are positively associated with student achievement and that additional teaching methods courses had "more powerful effects" than additional preparation in the content area. Monk (1994) stated, "it would appear that a good grasp of one's subject area is a necessary but not a sufficient condition for effective teaching" (p. 142).

The literature on pedagogy also includes considerable research on the preparation of teachers for students of diverse backgrounds. Cochran-Smith, Davis, and Fries (2003) noted in their synthesis that the impact of preparing teachers for a diverse population has rendered inconsistent results, though there have been studies that suggest a positive impact. Further, they point out that measures are not well developed and that there are few longitudinal or large-scale studies for general application. Although the research in preparing teachers for diverse student populations has not yet conclusively uncovered a system that best prepares prospective teachers, the persistent disparities that exist both in terms of educational resources and achievement between students of color and their White peers clearly points to a need to address these issues in teacher preparation. Additionally, there is evidence that teachers leave teaching because of "unmotivated" students or classroom management (Ingersoll, 2001), both issues of pedagogy that are not content specific.

Hence, what we see in the research is the term "pedagogy" as both the teaching of the content (as in Monk) as well as referring to the skills of motivating and managing students, and working with students of diverse (ethnic, socioeconomic, and learning abilities) backgrounds. Therefore, the term "pedagogy" is used to encompass both content specific as well as non-content specific skills. I propose that novice teachers need both content and non-content skills, and that teacher preparation must explicitly address both. Hence, I will use the term "pedagogy" to refer only to non-content specific aspect to teaching and will use "pedagogical content" to refer to content specific aspects of teaching.

Pedagogical Content Knowledge

Shulman (1986) was the first to introduce the term "pedagogical content knowledge." He introduced the notion of content specific pedagogy as part of his three-prong conceptualization of Teacher Knowledge. His conceptualization identified subject matter knowledge, pedagogical content knowledge, and curricular knowledge as the three categories of knowledge prospective teachers need. He conceptualized pedagogical content knowledge as "an understanding of what makes the learning of specific topics easy or difficult: The conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics" (p. 9). Since Shulman's introduction of "pedagogical content knowledge," several researchers of mathematics education have built on the conceptualization and argued that teachers need to know mathematics in a different way than other professionals that use mathematics (Ball et. al, 2008; Ball, 2000; Ma, 1999; Usiskin, 2000). These researchers have used the idea of pedagogical content knowledge in their conceptualization of the types of knowledge mathematics teachers need to teach (Hill, Ball, & Schilling, 2008; Hill, Rowan, & Ball, 2005; Leinhardt & Smith, 1985; Tirosh, 2000; Wilson, Floden & Ferrini-Mundy, 2002).

Shulman's constructs his argument for pedagogical content knowledge by pointing out that prospective teachers need more than an understanding of the content, they need an understanding of content that transcends being able to "do" into the ability to "explain" understanding to others. Hence, he notes that the objective of teacher preparation is to facilitate the "transition from expert student to novice teacher" (Shulman, 1986, p. 8).

Although Shulman does not isolate pedagogical knowledge as its own category of needed knowledge for teachers (as I have), he acknowledges that his conceptualization "does not intend to denigrate the importance of pedagogical understanding or skill in the development of a teacher or in enhancing the effectiveness of instruction" (p. 8). Rather, he argues that pedagogy must be linked to the content.

It is clear that pedagogical skills and knowledge are necessary for teaching. What is less clear is if there are two separate domains of pedagogical skills and knowledge; one that is directly associated with the teaching of the content and the other that is general and not associated with the content. In other words, are the skills and knowledge associated with explaining concepts, understanding student thinking, and error analysis of student work distinguishable from the skills and knowledge of managing a classroom, motivating students, and working with diverse student populations? If they are distinguishable, then teacher preparation must address both.

Curricular Knowledge

Shulman's (1986) conceptualization also proposes the idea that curricular knowledge is separate from either pedagogical content knowledge or subject matter content knowledge as a type of knowledge for teaching. He characterizes curricular knowledge as a full grasp of the materials and programs that serve as the "tools of the trade" for teaching the content (1987, p.8). Hill, Ball, and Schilling (2008) borrow from Shulman in their conceptualization of mathematical knowledge for teaching. They conceptualize mathematical knowledge for teaching as containing two overarching domains: subject matter knowledge and pedagogical content knowledge, each with three subcategories. They argued that curricular knowledge is a subcategory of pedagogical content knowledge. Further, they found that although the conceptualization of the pedagogical content knowledge "is far from straight forward" (p. 396), there appears to be evidence that their three components are indeed separate from each other and that they are distinct from pure content or pedagogical knowledge.

Though curricular knowledge has been acknowledged as a domain of teacher knowledge, it has received little empirical attention in the research literature. However, Ball (2009) argues that coherent curriculum is essential and directly points to a lack of a central or common curriculum as an impediment to the improvement of mathematics instruction and achievement in the United States. Further, she argues that teachers need to examine during their preparation the curriculum they will be using to teach to fully understand how to teach it and how students may perceive or interact with it. A teacher's ability to assess that curriculum is paramount to effective instruction.

## The Interplay of the Four Domains

I propose that the knowledge and skills pre-service teachers need in order to develop and become novice teachers fall into four domains: *content knowledge*, *pedagogical knowledge*, *pedagogical content knowledge*, and *curricular knowledge*. Further, I suggest that each of these domains must be explicitly addressed in teacher preparation rather than assuming that each will develop as a result of pre-service teachers taking general mathematics and pedagogy courses. The theoretical framework I am suggesting focuses only on the knowledge and skills pre-service teachers need to develop during their preparation in order to move from expert student of college mathematics to novice teacher of secondary mathematics. It is not intended as a conceptualization of the totality of mathematical knowledge for teaching of an experienced or master teacher.

This conceptual framework builds on the work of Ball et al. (2008), Hill et al. (2008), and Shulman (1986), while taking into account all the aforementioned literature. In this conceptualization, content knowledge, pedagogical knowledge, pedagogical content knowledge and curricular knowledge are related to one another in a loosely coupled system where the separate knowledges inform and support one another, but can and often do develop separately. Hence, all four domains must be systematically developed during teacher preparation.

The proposed conceptual framework distinguishes pedagogical content knowledge from both content (or mathematical) knowledge and pedagogical knowledge because teacher preparation must both develop mathematical knowledge specific to teaching and develop a pre-service teacher's ability to teach. Additionally, by clarifying that there is a distinction between general pedagogical skills, such as classroom management or working with students who are English language learners, from content specific pedagogical skills, such as the teaching of division of fractions, the framework acknowledges that for pre-service teachers, there is distinction between pedagogical skills that are related to content from those that are not. Further, though Shulman (1986) and Hill et al. (2008) do not conceptualize pedagogical knowledge as its own category, separating it from mathematical (content) knowledge is supported by teacher quality research (Cochran-Smith, 2001; Darling-Hamond, 2000b, Darling-Hammond & Youngs, 2002; Kanstoroom & Finn, 1999; Melnick & Pullin, 2000; Wilson et al., 2001). Separating curricular knowledge from content knowledge, pedagogical knowledge, and pedagogical content knowledge is supported by both Hill et al. and Shulman.

The conceptual framework (Figure 2) acknowledges the ideas of Shulman that teacher preparation must facilitate a transition from expert student to novice teacher, and that the domains are interconnected. The reason some of the components of Hill et al.'s conceptualization of the mathematical knowledge for teaching have been eliminated for the conceptualization are two-fold: (a) it acknowledges that teacher preparation can only prepare a prospective teacher to be a novice teacher, not a master teacher with the full range of mathematical knowledge for teaching; and (b) it acknowledges it is difficult for a novice teacher to discern between knowledge of content and student and knowledge of content and teaching. In other words, these two domains described by Hill et al. have been collapsed into one domain for this conceptualization.

All of the knowledge and skills across domains are variably coupled. For example, in order for a teacher to develop much of the knowledge and skills in pedagogical content knowledge, she must first be able to "do" the mathematics she is trying to "teach." Hence, in order for a teacher to be able to help a student understand why one cannot simplify 2x + 3y further, but one can simplify (2x)(3y), the teacher must first know how to "do" both computations and must understand the underlying principals of addition and multiplication that govern the simplification of each. Once she understands the mathematics, she can then move to understanding what makes the process difficult for a student to understand, what are the common errors students make with both the simplifications, and how to help a student connect models of addition and multiplication with the computations. Therefore, although the skills are coupled, they are distinct. However, being able to simplify algebraic expressions does not ensure that an individual can teach it. Phrases such as "like terms," that are used and understood mathematically are inherently difficult for students and must be linked to prior understandings. The ability to do this is pedagogical content knowledge, which is linked but distinct from mathematical (content) knowledge.

Other knowledge and skills are more loosely coupled. For example, knowledge and skills in motivating and managing students (pedagogical knowledge) can be completely separated from the content (content knowledge or pedagogical content knowledge) such as rewarding students for good behavior with tokens, or it can be directly related to content when mathematics teachers motivate and manage students by using engaging mathematical lessons.

The four proposed domains are independent but interrelated and become more interrelated as the novice teacher becomes more experienced and expert. They each are necessary to do the work of teaching mathematics and supporting one another. I propose that teacher preparation, as it is currently structured, does not develop each domain sufficiently, thus leaving novice teachers inadequately prepared to begin the work of teaching. I suggest that each of the four domains must be explicitly addressed in teacher preparation. Since they are currently not being directly and explicitly addressed, novice teachers are developing the knowledge and skills while they are teaching.

## Definitions of the Four Domains of Teacher Knowledge

*Pedagogical Knowledge* is the knowledge and skills associated with non-content specific aspects of teaching and learning such as the knowledge and skills needed for teaching English language learners and students requiring special education services, classroom management, multicultural education, learning theory, and motivation strategies (Cochran-Smith, Davis & Fries, 2003; Fennema & Franke, 1992).

*Mathematical Knowledge* (content knowledge) is the ability to accurately represent mathematical ideas, provide mathematical explanations for common rules and procedures (at the secondary level), understand content trajectories (the origin and extension of core concepts and procedures), apply mathematical ideas, use mathematical language and conventions, and reason and do mathematical proofs (Ball et al., 2008; Ferrini-Mundy et al.; Hill et al., 2008). In this definition, I mean specifically the mathematical concepts directly related to secondary mathematics.

*Pedagogical Content Knowledge* is the ability to impart mathematical understanding to students, which includes the capacity to analyze student mathematical work and interpret what the student does and does not understand, design, modify and select mathematical goals to meet the needs of students in the context of the course, explain mathematical ideas in various manners, deconstruct complex mathematical ideas and attach fundamental meaning to symbols and algorithms in a manner that both maintains the integrity of the mathematics and is accessible to students, and enable students to see and apply content trajectories (Ball, 2000; Ferrini-Mundy et al., 2008; Hill et al., 2008; Shulman, 1986). Again, as in mathematical knowledge, I am specifically talking about the mathematics that is being taught at the secondary level.

*Curriculum Knowledge* is the knowledge and skills around the State Core Curriculum (or other state's core/guiding curriculum); programs designed for the teaching of mathematics at different levels; instructional materials available including textbooks, supplementary materials, software programs, and internet tools; and characteristics that serve as both the indication and contraindication for the use of a particular curriculum or program material (Shulman, 1986).

## Summary of Conceptual Framework

Together these four domains—pedagogical knowledge, mathematical knowledge, pedagogical content knowledge, and curricular knowledge—comprise the knowledge and skills that secondary mathematics teachers need in order to be successful as they begin their work as mathematics teachers. The four domains are coupled and define what teachers need to successfully transition from an expert student of college mathematics to a novice teacher of secondary mathematics. These domains are not intended to define the totality of knowledge of a master or experienced teacher.

## Research Questions and Hypothesis

This study seeks to answer the following questions:

1. Do novice secondary mathematics teachers' perceptions of their knowledge and skills in the work of teaching fall into the four proposed conceptualized domains—mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge?
2. To what extent do novice teachers perceive they are prepared to do the work of teaching secondary mathematics?
3. Where do novice mathematics teachers report they gained their knowledge and skills for teaching?
4. Do novice mathematics teachers who were prepared at different institutions report any differences in their knowledge and skills?

This study builds on the following hypotheses that guide theoretical and methodological decisions herein:

Hypothesis 1: Novice teachers perceive that their work falls into four separate domains—mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge.

Hypothesis 2: Novice teachers vary in the degree to which they feel prepared in each of the four conceptualized domains—mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge.

Hypothesis 3: Novice teachers will report that they gained mathematical knowledge in college, but will report that they gained pedagogical, pedagogical content, and curricular knowledge outside of college.

Hypothesis 4: There will not be a discernable difference between teacher preparation institutions in terms of the perceptions of novice teachers' beliefs in their preparedness.

## Overview of the Study

Chapter 2 of this dissertation synthesizes the research literature on teacher preparation with particular emphasis on teacher preparation in mathematics upon which the conceptual framework of the study rests. Chapter 3 details the methodological procedures utilized in conducting this research including creation of the survey instrument, sampling procedures, and statistical tests used herein. In Chapter 4, results of the analysis are presented. Finally, in Chapter 5, policy implications and conclusions of the proposed theoretical framework and empirical findings are offered.

CHAPTER 2

# THE LITERATURE ON TEACHER PREPARATION AS IT INFORMS SECONDARY MATHEMATICS TEACHER PREPARATION AS A POLICY ISSUE

## Introduction

Teacher education as a policy issue has become a high profile theme in educational research in recent years (Allen, 2003; Ballou & Podgursky, 2000; Darling-Hammond, 2000a, 200b, 2001; Wilson & Floden, 2002). Policy researchers look at such questions as: What are the attributes of a "quality" teacher? Does licensure make a difference in student achievement? What is the most effective way to prepare individuals to teach or is preparation even necessary? Are teacher preparation programs in specific content areas, such as mathematics, affecting student achievement outcomes? Are there other attributes besides teacher preparation that contribute positively (or negatively) to teacher performance? This perspective informs how I attempt to answer these questions. For example, when looking at teacher quality, one perspective is to measure quality by assessing student outcomes, another is to assess teacher attributes such as licensure, preparation, academic ability, etc.

This dissertation is informed by the perspective that the role of educational policy in teacher preparation is to ensure that only those well prepared to do the work of teaching enter the classroom in the first place. The identification of structures that ensure that every student has a well-prepared quality teacher in mathematics is my ultimate goal. Deborah Ball captured the perspective of this dissertation in her 2009 testimony to Congress when she said, "many people have ideas about improving 'teacher quality.'" Some proposals focus on how to identify and fire incompetent teachers. Others seek to increase the pay of teachers who are effective in producing student learning. Still others create incentives to attract more bright people to the teaching profession. Although these all make sense, at least in part, not one of them sufficiently addresses the core problem: that of ensuring that every teacher, in every classroom, can do the work we are asking of them. What we need is quality teaching, as explained by Ball (2009), "this is a problem of training, both initial and continuing, and not merely one of sanctions, rewards, or other incentives" (p. 1). Hence, this dissertation focuses on how to better prepare candidates wishing to enter the field of teaching, specifically secondary mathematics.

This dissertation will focus on mathematics teacher preparation from the perspective of a novice mathematics teacher. It seeks to understand how well prepared they feel to do the work of teaching secondary mathematics as a means of looking at the current structure of teacher preparation in secondary mathematics. The research on teacher quality, teacher licensure, student access to quality teachers, teacher preparation, and the state of mathematics education in the United States frames this dissertation. The conceptual framework emerged from the foundational research in these areas.

## Teacher Quality

The literature on "teacher quality" approaches the topic from two broad and often intertwining perspectives: pupil performance and teacher attributes (Cochran-Smith, 2005; Cochran-Smith & Fries, 2005). Researchers who approach teacher quality from the perspective of student achievement note that there are variations in student achievement attributable to teachers, but that the measurable differences are not attributable to common indicators such as teacher experiences, preparation, or test scores. This perspective is embodied by the notion that, "good teachers are ones who get large gains in student achievement for their classes; bad teachers are just the opposite" (Hanushek, 2002, p. 3). At the core of this perspective is the idea that teachers play the single biggest role in value added to student achievement; a role larger than previous achievement, class size, ethnic, or socio-economic status (Rivers & Sanders, 2002). From this perspective, teacher quality is operationalized by student achievement. Therefore, from a policy perspective, this approach implies that organizational measures, such as incentive pay for teachers or school accountability measures, are appropriate procedures for improvement in education.

Researchers such as Darling-Hammond (2000a, 200b) and Darling-Hammond, Chung, and Frelow (2002), have advanced the second approach: the perspective that teacher quality can be assessed in terms of teacher characteristics, attributes, or qualification. This perspective emphasizes the link between what teachers know and can do to teacher preparation and licensure. Research from this perspective seeks to uncover a link between teacher characteristics, such as college characteristics and tested skills, and knowledge and student achievement (Wayne & Youngs, 2003). The implication to policy from this perspective is that quality teachers can be identified and recruited to improve education.

Both of these perspectives of teacher quality strive to increase student achievement. However, from a policy perspective, the first pays little attention to who or how a candidate is placed in the classroom. Rather, it focuses on if the teacher is effective *after* she or he has spent at least a period of time in the classroom with students. The second attempts to pre-identify who will be a quality teacher before she or he enters the classroom and begins working with students. This second approach does not preclude awards for effective teachers or the elimination of ineffective teachers after they enter the classroom; rather, it attempts to ensure that only the most likely to be effective enter the classroom in the first place. Theoretically, if only the most likely candidates to be successful are allowed in the classroom in the first place, student achievement will increase and there will be less of a need to eliminate those teachers that are not getting student achievement gains.

## The Impact of Academic Ability of Teachers on Student Achievement

A great deal of research on teacher quality has focused on the general ability of the pool of prospective and active teachers. In 1983, *A Nation at Risk: The Imperative for Educational Reform* (National Commission on Excellence in Education) reported that, "not enough of the academically able students are being attracted to teaching....Too many teachers are being drawn from the bottom quarter of graduating high school and college students" (p. 22). The research of the time supported that idea (Chapman & Hutcheson, 1982; Kerr, 1983; Vance & Schlechty, 1982). However, there soon emerged research indicating that methods employed in the above and similar research concluding that the academic abilities of teachers were lower than those of other college majors were flawed. For example, GPAs of high school students who *intended* to teach rather than those who actually went into teaching were compared in the earlier research, rendering false conclusions (Barger, Barger & Rearden, 1988; Gitomer, Latham & Ziomek, 1999; Hanushek & Pace, 1995).

In research done by Henke, Geis, Giambattista, and Knepper (1996) using the Bachelor's and Beyond Survey (BBS) for 1992 to 1993, college graduates, students interested in teaching, teacher education students, teachers, and those who remain in teaching had lower scores on college entrance exams (only 20% were in the top quartile for the SAT or ACT tests), confirming previous research. However, they had higher high school and college GPAs. This data was for both elementary and secondary teachers. However, when disaggregated, secondary teachers or teacher candidates scored in the top quartile of the SAT and ACT tests at the same rate as nonteachers.

Also using High School and Beyond Survey data, Vegas, Murnane, and Willett (2001) found that higher proportions of Black, Hispanic, and Native Americans entered teaching compared to Whites and particularly compared to Asian Americans. All female students with higher academic abilities were less likely to go in to teaching than other fields; however, there was no discernable difference between White and Black females who entered teaching than those who did not, although there was a considerable difference for Hispanic females. For males, Blacks and Whites with high-test scores were somewhat more likely to go in to teaching than those with low scores.

Gitomer et al. (1999) explored the relationship between ACT and SAT scores of 272,000 candidates and their Praxis I and II exams. As in previous studies, they found that ACTand SAT scores rose at each successive juncture through the process of entering teaching with teacher candidates who passed the Praxis I exam scoring slightly higher on the SAT than the national average. However, at the Praxis II juncture, they found that the average SAT score was lower than the national average. Again, when disaggregated they found that those entering elementary, special education, and physical education had substantially lower scores, while those entering secondary content areas had comparable or higher average scores. They concluded that, "for content area specialists, the issue appears to be one of increasing quality" (Gitomer et al., p. 38).

Research on academic characteristics of teachers finds that secondary teachers tend to have higher SAT scores than other teachers (Gitomer et al., 1999; Henke et al., 1996). Teachers that scored in the bottom quartile of the SAT were more likely to teach at the elementary level, while those from the top quartile were more evenly split between elementary and secondary. At the secondary level, those from the top quartile were nearly twice as likely to teach math or science and four times as likely to teach English (Henke, Chen, & Geis, 2000).

The notion that teaching is a cognitive endeavor that requires complex skills, such as the ability to think and reason, clearly predicates the notion that SAT and ACT test scores are an important predictor of teacher quality (Vegas et al., 2001). However, recent research suggests that the correlation between teacher general ability, as measured by such scores, and student achievement is not as strong as might be expected (Darling-Hammond, 2000a, 200b; Murnane et al., 1991). For example, by reanalyzing the large Coleman et al. (1966) database, Ehrenberg and Brewer (1995) found that for elementary schools, teacher verbal scores were associated with higher gains for students. In particular, they found that higher verbal scores for Black elementary teachers were associated with higher gains for Black and White students, but that higher verbal scores for White elementary teachers were only associated with higher gains for White students. For secondary students, higher verbal scores of teachers were associated with gains for White students, but not for Black students. White teachers' verbal aptitude was associated with gains for both Black and White students, while verbal aptitude for Black teachers was not associated with either group.

Intellectual ability of prospective teachers or active teachers has long dominated discussion of teacher quality and consequently educational policy. For secondary teachers, however, there is evidence that they already have higher abilities as measured by college entrance exams than general college graduates. Therefore, whether or not there is an impact on student achievement for higher general abilities, requiring higher abilities will likely not change the pool of secondary teachers. Nevertheless, the claim of the first Title II report that verbal ability and content knowledge of teachers are the most important attributes of highly qualified teachers will continue to perpetuate research on the correlation between general abilities of teachers and student achievement.

## The Impact of Teacher College Coursework on Student Achievement

There is significant empirical evidence that teacher content knowledge is important for student achievement (for example, Darling-Hammond et al., 2002). The question, though, is not if content knowledge is important, but rather *what* content knowledge is important (Floden & Menikeii, 2005) and *how* content knowledge is used to teach: "Teachers highly proficient in mathematics or writing will help others learn mathematics or writing only if they are able to use their own knowledge to perform the tasks they must enact as teachers" (Hill et al., 2005, p. 376).

The research on subject-specific preparation falls into three broad categories: (a) the correlation between the amount of subject matter coursework and either student achievement or teacher evaluation, (b) teachers' subject matter knowledge, and (c) the impact of particular subject matter coursework (Floden & Menikeii, 2005). The literature from all three perspectives helps to shed some light on *what* coursework is most effective for teachers to ensure teachers are best prepared, but not necessarily *how* teacher coursework is applied in the classroom. This is because the majority of the research in this area is correlational in nature. Further, it is important to look at the research as it applies to specific grade level and content area.

### The Correlation Between the Amount of Subject Matter Coursework and Either Student Achievement or Teacher Evaluation

There is strong evidence that there is a correlation between teachers' subject matter knowledge and teacher effectiveness for all teachers, K-12 (Wilson et al., 2001, Wilson & Floden, 2002). In these studies, subject matter knowledge is operationalized by the amount of coursework taken in the subject and effectiveness is measured by ratings of teacher performance or tests of students' achievement. Most of the studies focus on grade level or content area.

A meta-analysis by Druva and Anderson (1983), for example, focused on science course taking of teachers and student outcomes as measured by achievement, performance, and attitude towards science. They found that for biology teachers, the number of biology classes taken related positively to student achievement. Additionally, student attitudes towards science at all grade levels related positively to the number of science classes taken by the teachers. Lastly, the relationship between teachers' training in science and cognitive student outcome increased with the number of science courses taken by the teacher.

At the elementary level, Hawkins, Stancavage, and Dossey (1998) looked at the correlation between college major and licensure and student achievement outcome in mathematics, as measured by the National Assessment of Education Progress (NAEP) in 1996, and found that fourth-grade students that had teachers with college majors in mathematics education or education did better then those with teachers who had majors in other fields. They also found that the type of teaching certificate (mathematics, education, or other) held by the teacher was not related to student achievement. For eighth-grade students, students with teachers that had college majors in mathematics out-performed those that had degrees in other fields. The students of teachers with licensure in mathematics also had higher achievement than those with teachers who held other licensure.

In a survey research and comparative population study using a 3-level linear hierarchical model of students' growth in academic achievement, Rowan, Correnti, and Miller (2002) found that neither teachers' degrees nor licensure status had significant effects on achievement growth in reading for elementary students, although they found that experience did. Experience mattered more for later grades than for early grades. For mathematics, in terms of licensure and experience, results were similar. Licensure did not matter, but experience mattered for later grades. More interesting, however, was that they found that students taught by teachers with advanced degrees in mathematics actually did worse than students with teachers that did not have a degree in mathematics.

This negative effect was actually the most significant they found, though not surprising given the students were elementary aged.

There is considerable research in the area of secondary mathematics reporting a positive correlation between the amount of study in mathematics for a teacher and measures of student achievement (Goldhaber & Brewer, 2002; Hawkins et al., 1998; Rowan et al., 2002; Wenglinsky, 2002). However, two studies found no significant association (Hawk, Coble, & Swenson, 1985; Monk, 1994).

Monk (1994) and Monk and King (1994) found a positive overall association between the amount of mathematical coursework a teacher had in college and student achievement, but they found that there were differential effects for students at different levels of mathematics. Further, they found that pedagogical training is as least as important as mathematical knowledge. Students in more advanced classes benefited form teachers with more mathematical coursework, but students in remedial classes did not benefit from teachers with more coursework (this seems to mirror the findings of Rowan et al., 2002). Overall, their research indicates that the strongest association between student achievement and teacher coursework occurred for the first five mathematics classes a teacher took; after that, the student achievement effect diminished.

While there seems to be a correlation between content coursework and student achievement, most of the research in this area focuses on mathematics. While the evidence on a whole seems to point to the conclusion that teachers with more knowledge in mathematics are more likely to have students with higher achievement, it seems clear that the effects are different for different groups of students and that advanced coursework in mathematics benefits only students at advanced levels of mathematics. Of particular importance are Monk's findings that benefits for student achievement diminish after the first five classes of college level mathematics. Why these classes have the most effect on student achievement in secondary mathematics has not been studied.

Teachers' Subject Matter Knowledge

Research in teachers' subject matter knowledge looks at whether the college coursework or other background provides a prospective teacher the subject matter knowledge she or he needs to successfully teach. The assumption is that if teachers have strong subject matter knowledge, then their coursework or teacher preparation program was effective. If their subject matter knowledge is weak, then their college coursework or teacher preparation was not effective. Further, the assumption is that it is important for a teacher to understand their subject matter well so that they can think flexibly as they work with students to help them understand the content (Ball, 2000; Ma, 1999). As with the previous research domain, correlation between subject matter knowledge and student achievement, the content area of mathematics dominates this area of research—both elementary and secondary, though there is some research in other content areas.

In the content area of English and language arts, for example, one study found that teachers know aspects of English, but do not understand underlying principles of grammar that allow them to move beyond simply stating the grammar rules (Kennedy, 1998). Holt-Reynolds (1999) concluded that courses taken to complete an English major left many teachers without the knowledge they needed to teach the subject, such as how to think about what distinguishes works of literature from other works. Similar results were found in a study of history teachers where of the 4 teachers studied, only one had an accurate understanding of history as a subject beyond date and name facts (Wilson & Wineburge, 1988).

Results of these studies are similar to what research on teacher content knowledge in mathematics finds. Current work strongly suggests that many, particularly novice, teachers of mathematics do not fully understand the mathematics they teach or are not able to explain concepts in meaningful and flexible ways to students. For example, in examining 10 preservice elementary teachers and 9 preservice secondary teachers, Ball (1990b) found that most could not give meaningful explanations of the mathematics that they would be teaching. For instance, most of the subjects could not give a meaningful explanation for why it is not possible to divide 7 by 0. Based on the data, Ball concluded the mathematical understanding of the subjects tended to be rule-driven and thin. She challenged three basic assumptions about teacher knowledge of mathematics for teaching: (a) if you can "do" the mathematics, you can teach it; (b) pre-college education provides teachers with much of what they need to know about mathematics for teaching; and (c) majoring in mathematics ensures subject matter knowledge. It is the third assumption that is most interesting from the perspective of policy around secondary mathematics teacher preparation and this dissertation. Ball's research found "less difference in substantive understanding between elementary and secondary teacher candidates than one might expect (or hope). Although the latter, because they are mathematics majors, had taken more mathematics, this did not seem to afford them substantial advantages in articulating and connecting underlying concepts, principles, and meanings" (p. 463). The research did, however, find substantive differences in teachers' confidence about doing mathematical tasks.

Ball's research was the impetus for other scholars to look at the readiness of teachers to teach mathematics. The term *Profound Understanding of Fundamental Mathematics* (*PUFM*) was coined by Ma (1999) in examining 23 American and 72 Chinese teachers' understanding of four domains of fundamental mathematics: subtraction with renaming, multi-digit multiplication, division of fractions, and the relationship between perimeter and area. She concluded that while Chinese teachers held a solid knowledge of these topics, the American teachers had a pseudo-conceptual understanding of the topics. When Ma asked the teachers to divide 1¾ by 1/2, nine American teachers did not get the right answer, while all of the Chinese teachers were able to do the computation. Using the same problem, 6 American teachers could not create a story context for the problem. Sixteen created stories with misconceptions and only 1 provided a conceptually correct problem situation, although it was a pedagogically problematic representation. All the Chinese teachers were able to provide either a partitive or measurement story situation for the problem. Ma concluded that low-quality school mathematics education (K-12) reinforces low-quality teacher knowledge of school mathematics and that the only way to break the cycle is to refocus attention on teacher preparation in mathematics.

Monk (1994) supported Ma's and Ball's findings that being able to "do" mathematics did not necessarily translate to being able to teach or apply understanding to the mathematics being taught. He found that teachers with more math coursework (higher subject matter knowledge in mathematics) had a positive effect for students in advanced classes, but that there was no effect for students in remedial classes. In other words, the advanced subject matter (mathematical) knowledge teachers had was not what they needed for remedial students; hence, the additional subject matter knowledge teachers had as measured by coursework was not being connected by the teachers to the subject matter they were teaching to the remedial students.

The implications of the above research, specifically around mathematics, for this dissertation is that teachers do not seem to have the depth and flexibility of understanding they need in mathematics to teach it to children at all levels, and that teacher preparation needs to refocus its attention on better preparing prospective teachers for the work they will be doing in teaching mathematics. The fact ~~that~~ there is extensive research in mathematics understanding of prospective teachers and its correlation to student achievement should give policy makers pause. The question, however, is what knowledge and skills in mathematics teachers are, and are not, gleaning from their preparation? How can teacher preparation in mathematics improve?

Impact of Particular Subject Matter Coursework

As with the other two areas, the correlation between the amount of subject matter coursework and either student achievement or teacher evaluation, and teachers' subject matter knowledge, the impact of *particular* subject matter coursework has significantly more research from the perspective of mathematics education. However, the research in other subject areas supports the finding in the subject area of mathematics.

In a study of 8 prospective secondary social studies and language arts teachers, 3 of who were reported on, Clark and Medina (2000) found that the use of narratives supports changes in teachers' views of knowledge, critical understanding of literacy and multiculturalism, and disrupts stereotypical conceptions of others. Further, they found that the narratives facilitated prospective teachers' ability to connect to others' narratives and recognize the limitations of their own perspectives. An individual class also facilitated change in the perspectives of elementary teachers with the use of videotapes and transcriptions. The teachers' perspectives of science evolved from thinking of science and teaching it as static and fact-driven to a more sophisticated process of scientific reasoning (Smith & Anderson, 1999).

In mathematics, as with the studies mentioned above, the focus of the coursework studied was to help teachers think about working with and teaching mathematics in different ways. Research found evidences that teachers' perspectives of how to use modeling (Zbiek, 1998), inquiry (McNeal & Simon, 2000), small group discussion (Civil, 1993) and problem solving (Emenaker, 1996) effectively improved teachers' abilities in these domains. Thus, the research points to the positive effect single courses can have on the practice of teachers.

### Teacher Quality Conclusion

In summation, teacher knowledge has a positive effect on student achievement, but exactly what knowledge and skills are needed by teachers is still not completely clear. Further, there is clear evidence that teachers do not necessarily possess some specific knowledge and skills they need for teaching. This seems to be particularly true of mathematics where teachers are generally able to do the mathematics they teach, but are not necessarily able to explain it. Lastly, individual classes seem to affect change in teachers' thinking and practice about teaching, even in mathematics. Taken as a whole, these conclusions point to policy reforms in teacher preparation that are not only *needs*, but are likely to be successful if implemented well. Implementing policy changes around teacher preparation may better prepare prospective teachers, thus increasing the likelihood that only quality teachers enter the classroom.

The two broad intertwining approaches of teacher quality (pupil performance and teacher attributes) introduced at the beginning of this section both seek to ensure excellence in education. The argument proposed in this dissertation is that by identifying the domains that best categorize the skills and knowledge teachers' need as they begin the work of teaching, preparation programs will be better able to design coursework to fit those needs. Further, it is vital that preparation programs understand both how novice teachers view their work and how well prepared they feel to do it. In other words, teachers may have extensive coursework in mathematics (content), but if they feel they are not well prepared to teach it, or if they feel they are learning it while teaching rather than from their coursework, then their teacher preparation program did not adequately prepare them for their work. Hence, gathering information about this from novice teachers is vital.

## Teacher Licensure

Although NCLB has put to rest the question of *if* licensure is needed for an individual to be identified as a "highly qualified" teacher, it did not put to rest the question of what processes or measures quantify an individual eligible for licensure. Teacher licensure is a politicized issue with questions that include the merit of teacher preparation, what skills and knowledge teachers must posses, and who should oversee the licensure of teachers (Wilson & Young, 2005).

## Testing as Part of Licensure

Wilson and Young (2005) define "licensure" as the process by which states assess the qualifications of an individual to be a teacher. Wang, Colement, Coley, and Phelps (2003) found that in the United States, teacher education and licensure is much more decentralized than several other countries. Although licensure in the United States is decentralized, there are some commonalities. According to the National Association of State Directors of Teacher Education and Certification (NASDTEC), currently 42 states require some form of testing as part of licensure, with 37 states requiring a basic skills test for teachers (Wilson & Young, 2005). For much of United States history, the main route to teaching was through passing some sort of examination, usually offered at the local or county level (Angus, 2001).

Angus (2001) reports that early examinations, from the 1800s, often consisted of not only content knowledge but also contained questions regarding "moral fiber," ability to manage a classroom, and sometimes questions regarding religious affiliations. By the late 19th century, however, a growing number of professional teachers began to criticize the exams as being too easy and therefore allowing "incompetent" teachers into the ranks. As a result, professional training institutions, typically normal schools or teacher colleges, began to emerge offering coursework that included educational history, psychology, educational foundations, teaching methods, and assessment (Wilson & Young, 2005). Testing as part of licensure was seen during the latter part of the 1800s and early 1900s as a back door approach to teaching. By the mid-1900s, the United States began to see a teacher surplus. Because of this, coupled with the fact that urban areas were looking for a way to "discern" between teacher candidates and the emergence testing firms, teacher testing reemerged. Baker (2001) points out that in the South, for example, Black teachers were typically paid less than their White counterparts in the first half of the 1900s. When this practice came under attack, many districts turned to the National Teacher Examination (NTE) on which White teachers typically outperformed Black teachers. They thus "eliminated" the policy of pay associated to race, but were able to continue the practice because the NTE favored White teachers—a strategy Educational Testing Services seemed to endorse. However, by 1971, mounting criticism of the practice lead ETS to issue guidelines on proper use of the NTE. They also attempted to eliminate test bias.

In recent years, testing, at least as part of licensure, has again become in vogue. The most widely used examination today is the Praxis Series, which replaced the National Teacher Examination in 1993. The Praxis provides three types of examinations: (a) a prerequisite content knowledge exam, (b) subject-specific content knowledge and pedagogical exam, and (c) an interactive teaching skill exam.

Testing sets a minimum standard on the amount of knowledge a teacher has. However, it does not distinguish between minimally competent and "highly qualified" teachers (Mitchell, Robinson, Plake, & Knowles, 2001). In examining a sample of 40,000 teacher candidates, Wenglinsky (2002) found that prospective teachers from private institutions scored higher than those from public institutions, university prepared candidates outperformed college prepared candidates, and those prepared at larger institutions did better than those at smaller institutions. When socio-economic status and prior test scores were controlled, Wenglinsky found that university-prepared candidates still outperformed college-prepared candidates, and private institutions still produced candidates better prepared than those from public institutions.

Of particular concern, however, is the fact that pass rates on the Praxis differ substantially by ethnicity. Gitomer et al. (1999) found that White candidates did substantially better on Praxis I and Praxis II than did candidates from underrepresented races and ethnicities (Praxis I: White, 82%; Asian American, 76%; Hispanic, 69%; Black, 46%. Praxis II: White, 91%; Asian American, 75%; Black, 69%, and Hispanic, 59%). They concluded that increasing requirements on the Praxis would adversely affect minority candidates entering teaching.

## Research on the Effectiveness of Licensure

In a study by Darling-Hammond (2000a, 200b) using data from the 1993 to 1994 School Staffing Survey and the National Assessment of Educational Progress mathematics and reading assessments (1990, 1992, 1994, and 1996) to examine the correlations of policy and student achievement, teacher quality characteristics such as licensure status and degree in the field were positively associated with student outcomes. Further, she reported that teachers with full licensure are the most important determinant of student achievement.

An earlier study by Hawk et al. (1985) that examined differences in student achievement in math for 18 teachers licensed in mathematics and 18 who held licensure in other areas found that student achievement gains were greater for the students with the in-field teachers. Further, the in-field teachers scored higher on instructional practices. Fetler (1999) examined high school staff characteristics and student achievement at 795 regular California high schools. Controlling for the effects of poverty, Fetler found that there was a strong negative correlation between teachers teaching with emergency licensure permits and student achievement. Fetler noted that in California, full licensure required demonstration of both subject matter knowledge and completion of a set of teacher education requirements. Emergency licensure permits, on the other hand, are generally given to candidates that have demonstrated subject matter knowledge but have not completed education requirements, or who have passed a basic skills test but have not completed either subject matter or education requirements for licensure.

## Teacher Testing and Licensure in Utah

In Utah, there are two primary routes to licensure for secondary mathematics: a "traditional" route and an "alternative" route. For a traditional route to secondary mathematics licensure, an institution designs a course of study that includes both mathematical and pedagogical content. The mathematics coursework generally aligns with the guidelines for a level II, III, or IV mathematics licensure (see Appendix B for a complete list of mathematics courses required for each level of endorsement), depending on whether the teacher candidate took extended mathematics classes, a minor in mathematics, or a major in either mathematics or mathematics education. A level II mathematics endorsement allows a teacher to teach mathematics through Elementary Algebra, and level III endorsement allows a teacher to teach through Algebra II, and a level IV endorsement allows a teacher to teach all secondary mathematics courses. The pedagogy classes required from institutions generally fall under the following categories: working with students with disabilities, working with students who are English language learners, management, curriculum and assessment, adolescent psychology, and content specific pedagogy. Once the teacher candidate completes the required coursework for secondary mathematics licensure as outlined by the institution, she or he must take the mathematics content Praxis 0069 Middle Level Mathematics exam or the 0061 Mathematics: Content Knowledge exam and earn a passing score. Once all these requirements are completed, the institution recommends the candidate for licensure to the Utah State Office of Education. The candidate then has a level I teaching license. The teacher then must complete the Entry Years Enhancement (EYE) requirements, which include 3 years of working with a mentor, completion and review of a teaching portfolio, 3 successful years of district and school evaluations, and achieving a score of 160 or higher on the Praxis II Principles of Learning and Teaching exam.

Individuals wishing to enter teaching through the "alternative route to licensure" (ARL) for secondary mathematics, must have a major in mathematics or closely related field (e.g., engineering, etc.). Individuals may then apply to the state for ARL status, which includes verification of degree and a criminal background check. The candidate may then apply for positions as an ARL. Once they attain a teaching position at a public, charter, private, or parochial accredited institution, the teacher candidate must complete a course of study, designed by the Utah State Office of Education for that individual based on his or her transcripts, within 3 years. Coursework falls under the same two domains that are required for individuals who seek licensure through traditional means. The teacher candidate must be fully employed as she or he completes the licensure courses. Once she or he completes the requirements outlined by the state and passes the Praxis I exam, she or he receives a level I license and must then fulfill the steps of a level II license as explained above.

According to the Educational Testing Service (ETS), the Praxis Middle School Mathematics exam (0061) has the following content categories:

1. Arithmetic and Basic Algebra (12 multiple choice questions; 20% of the exam)
2. Geometry and Measurement (10 multiple choice questions; 17% of the exam)
3. Functions and Their Graphs (8 multiple choice questions; 13% of the exam)
4. Data, Probability, and Statistical Concepts; Decrete Mathematics (10 multiple choice questions; 13% of the exam)
5. Problem-Solving Exercises (3 constructed response; 33% of the exam)

The Praxis Mathematics: Content Knowledge exam (0069) also has five content categories:

1. Algebra and Number Theory (8 multiple choice question; 16% of the exam)
2. Measurement (3 questions; 6% of the exam); Geometry (5 questions; 10% of the exam); and Trigonometry (4 questions; 8% of the exam)
3. Functions (8 questions; 16% of the exam); and Calculus (6 questions; 12% of the exam)
4. Data Analysis and Statistics (5-6 questions; 10-12% of the exam); Probability (2-3 questions; 4-6% of the exam)
5. Matrix Algebra (4-5 questions; 8-10% of the exam); Discrete Mathematics (3-4 questions; 6-8% of the exam)

Both the 0061 and 0069 exams relate directly to the mathematical content a teacher may teach students at grade level at the middle or high school level. As such, both exams are designed to assess how well teachers are able to “do” mathematics.

The Praxis II Principles of Learning and Teaching: Grades 7-12 exam (0524) has 7 sections:

1. Student as Learners (multiple-choice questions; 11% of the exam)
2. Instruction and Assessment (multiple-choice questions; 11% of the exam)
3. Teacher Professionalism (multiple-choice questions; 11% of the exam)
4. Students as Learners (short-answer questions; 11% of the exam)
5. Instruction and Assessment (short-answer questions; 11% of the exam)
6. Communication Techniques (short-answer questions; 11% of the exam)
7. Teacher Professionalism (short-answer questions; 11% of the exam)

The focus of the exam is on general pedagogical knowledge rather than specific or content pedagogical knowledge. In other words, all secondary teachers, regardless of the content she or he will be teaching, take the same examination. Hence, this exam does not assess pedagogical content knowledge. Further, it does not assess teacher knowledge of curriculum (curricular knowledge).

## Conclusion of Teacher Licensure

As seen above, there is strong evidence that teacher licensure is correlated positively to student achievement. Teachers with full licensure tend to have students who perform better than those who do not. Testing as part of the licensure process seems to ensure that those wishing to enter the teaching profession meet a minimum standard. On the other hand, testing seems to favor White candidates and thus tends to be a gatekeeper for individuals who are Asian Americans, Black, or Hispanic.

By requiring licensure as an indicator of being "highly qualified," NCLB has legitimized the licensure process. Though there is evidence that licensure is positively correlated to student achievement, assessments of teacher knowledge as measured by the Praxis exam, which is often part of licensure, tends to favor White candidates over candidates of color. This fact, in itself, is problematic. Of further concern is the fact that, in many states such as Utah, only mathematical knowledge and pedagogical knowledge are assessed as part of licensure. If the conceptualization offered herein proves to be valid, then assessing teacher knowledge in each of the four domains is warranted.

Licensure ensures that prospective teachers have been both trained in the knowledge and skills states deem as necessary for teachers and then (in the vast majority of states) assessed to see if prospective teachers have acquired that knowledge. However, requirements for licensure vary across the country and, as was pointed out earlier, teachers do not seem to have all the knowledge and skills necessary to do the work of teaching. Therefore, although licensure is linked to student achievement, licensure is not yet ensuring that those entering teaching are indeed fully ready to teach mathematics. The support NCLB has given to licensure as a measure of being "highly qualified" should be harnessed to ensure that only those best prepared to do the work of teaching are licensed.

Hence, we must clearly understand what the work of teaching entails, define the general domains in which that work falls, and then both train and assess candidates wishing to enter teaching in those domains. Currently, most preparation institutions and licensure processes identify those domains as "content knowledge" and "pedagogical knowledge." However, *what* knowledge in those domains is necessary is not completely clear. I have proposed a conceptualization that identifies what those two domains entail and have also added two other domains: pedagogical content knowledge and curricular knowledge. Asking novice teachers about how well prepared they feel to do their work and where they believe they gained their skills and knowledge to do the work of teachers will test the validity of the conceptualization. This will then inform policy makers how to better structure both preparation and licensure to ensure that only the best prepared candidates enter teaching.

## Improving Student Access to Quality Teachers

Evidence continues to mount that teachers are the most powerful determinants of student achievement (Darling-Hammond & Young, 2002; Sander & Rivers, 1996). Students who are assigned to several ineffective teachers in a row have substantially lower achievement than do students who are assigned to several highly effective teachers in a row (Sanders & Rivers, 1996), and, as was discussed above, teacher knowledge and teacher licensure are positively associated with student achievement. Thus, putting high quality teachers into every classroom is vital in order to increase student achievement for all students. However, the general "teacher shortage" across the country, and specifically in Utah, makes it difficult to find quality teachers for all classrooms.

### Secondary Mathematics Teacher Shortage

Nationwide, 58% of all secondary schools had problems filling at least one of the job openings in their school during the last decade. The issue, however, is most significant in mathematics. Fifty-four percent of secondary schools had English teacher openings, with about 50% of the schools (or 25% of secondary schools) having trouble filling those jobs. On the other hand, nationally, 54% of all secondary schools also had openings in mathematics during the last decade, with 80% having trouble filling those openings (that is 40% of all secondary schools nationwide) (Ingersoll, 2003).

The problem of finding qualified secondary teachers for mathematics has lead to an increase in out-of-field teacher assignments in classrooms across the country. Jerald and Ingersoll (2002) found that the rates at which teachers teach out of field varies greatly from state to state. They note that nationally, 24% of secondary classes in core academic subjects are taught by teachers without a major or minor in the content area they are teaching. When they disaggregated by poverty level of the school, they found that 34% of teachers in high-poverty schools did not have a major or minor in the subject they teach, while it is 19% in low poverty schools. They further disaggregated the data to look at out-of-field teacher assignments in mathematics and found that the problem is particularly acute for disadvantaged students, with 49% of math classes in high poverty secondary schools taught by teachers without a major or minor in math compared to 35% of all schools. The problem is significantly worse for middle schools, with 70% of high poverty middle schools having math classes taught by teachers without a degree in the field.

In Utah, 19% of core classes are taught by out-of-field teachers, 9% for the low poverty schools and 50% for the high poverty schools (Jerald & Ingersoll, 2002). This is an overall statistic, including all core subject areas. Given what we know about the acuteness of the problem in mathematics across the country, we can presume that the problem is the same in Utah.

Effects on Students of Poor Quality Instruction on Mathematics

Education as an Issue of Social Justice

There is strong empirical evidence indicating that students who complete rigorous coursework in mathematics (beyond Algebra II) prior to graduating from high school will both be more successful in and more likely to graduate from college in any area (Adelman, 1999). It is during the middle school years that students are either put on track for completing coursework beyond Algebra II, or they are derailed from the path (The Forgotten Middle, ACT, 2008). In order to take a math class beyond Algebra II in high school, a student must successfully complete Algebra as a 9$^{th}$ grade student.

The lack of quality teachers, particularly in high poverty middle schools and particularly in mathematics, is at the root of the achievement gap in mathematics. As mentioned above, students in disadvantaged middle schools are the most likely to have out-of-field teachers. Quality teachers during these years are essential in helping students become prepared for rigorous mathematics coursework in high school, which ultimately puts them on the path for higher education. Often, students in highly impacted middle schools are not able to take Elementary Algebra before entering high school, hence not putting them on the path to rigorous mathematics (Smith, 1996). Students often drop out of further mathematics coursework between 8$^{th}$ and 9$^{th}$ grade because of poor performance in prior years or attitudes towards mathematics (Ma & Williams, 1999).

Conclusion of Student Access to Quality Teachers

Equitable access to quality teachers and rigorous mathematics coursework is an issue of social justice. "The most urgent social issue affecting poor people and people of color is economic access….the absence of math literacy in urban and rural communities throughout this country is an issue as urgent as the lack of registered Black voters in Mississippi was in 1961" (Moses, 2001, p. 5). Nationally, despite significant attention paid to student achievement in mathematics, the gap between White and Black students on the NAEP assessment in mathematics has narrowed since 1990, but not since 2007. Between White and Hispanic students, the gap has had no significant changes at all since 1990. In Utah, the gap in student achievement on the NAEP mathematics exam is actually larger today than it was 16 years ago (NAEP, 2009).

Though this study is not intended to address teacher shortage (or teacher turnover), it does seek to improve mathematics teacher quality for all students. Ensuring that all students have quality teachers means that teacher preparation needs to address issues of instruction for diverse learners. Access to quality mathematics instruction is an issue of social justice that only recently has garnered much attention. Preparation to teach secondary mathematics must refocus its attention on ensuring that all learners both have access to quality teachers and that teachers are prepared to meet the needs of all learners. To that end, this study seeks to investigate novice teacher perspectives of their preparedness to do the work of teaching to see where improvements might need to be made.

## Teacher Preparation in Secondary Mathematics

Wilson et al. (2002) argue that a major gap in teacher preparation research is the lack of knowledge about how to prepare teachers for urban schools. Cochran-Smith et al. (2003) argue that new teacher education should not add on to the current structure of teacher preparation, but rather fundamentally reinvent structures to emphasize resources rather than deficit perspectives of diversity. Further, she argues that the fundamental ideological underpinnings of traditional teacher preparation need to be challenged to place knowledge of culture and racism front and center with the goals of preparing teachers for teaching for social justice and to value the cultural knowledge of local communities.

In an effort to build on these and other recommendations, the University of California at Los Angeles developed a teacher preparation program in which candidates were prepared on site in urban schools for teaching in urban schools. Only 10% of teachers from this program left after 5 years of teaching in urban schools compared to 50% of other new teachers (Quartz, 2003).

## Mathematics Teacher Preparation and Student Achievement

Since the launch of Sputnik in the 1950s, policy makers have been trying to reform mathematics education in the United States. That goal, however, remains elusive. Despite efforts such as the National Council of Teachers of Mathematics' (NCTM) *The Principals and Standards of School Mathematics* (Standards) in 1989 and later updates, there is clear evidence that reform is not penetrating into the classroom (Stigler & Hiebert, 1999).

Research by Stigler and Hiebert (1999) on how mathematics is taught in the United States, Japan, and Germany revealed that there is very little difference between how mathematics is taught *within* each country, but vast differences in how mathematics is taught *between* countries. In the United States, teachers show and tell students procedures on how to do mathematical problems and then have students practice those procedures. Students are seldom asked to problem solve or make mathematical connections. In both Japan and Germany, however, students start with problems and then must (within their particular cultural setting) find the procedure, theorem, and definitions. Practice of the new skill is only a small part of the lesson. Stigler and Hiebert concluded that the differences in mathematics education are cultural, and that a cultural change in how mathematics education is viewed is needed if change is to occur in the United States.

Ma (1999) notes that in the United States, teachers are expected to be able to teach as soon as they earn their degree and then are left alone with almost no assistance to fend for themselves, whereas teachers in China are mentored extensively in their beginning years. Further, she notes that in the United States, there is a cycle of poor K-12 education in mathematics that leads to poor instruction in mathematics. She suggests that that cycle can be broken by better teacher preparation in mathematics.

According to Darling-Hammond, "teachers teach from what they know. If policymakers want to change teaching, they must pay attention to teacher knowledge. And if they are to attend to teacher knowledge, they must look beyond curriculum policies to those policies that control teacher education and certification" (Darling-Hammond, 1990, p. 240). In other words, if we want to break the cycle of checking homework, asking questions about homework, watching the teacher demonstrate procedures on how to do new problems, then receiving homework to practice those procedures (Romberg & Carpenter, 1986), then teacher preparation in mathematics education will have to attend to changing how it prepares teachers. "The kind of teaching that reformers envision requires teachers to shift their thinking so that they have different ideas about what they should be trying to accomplish, interpret classroom situations differently, and generate different ideas about how they might respond to these situations" (Kennedy, 1999, p. 56).

## Vision for Reform in Mathematics Teacher Preparation

In the 1996 *Handbook of Research on Teacher Education*, Howey (1996) outlined a vision for mathematics teacher preparation that encompassed a strong focus on the diversity of learners and a focus on student thinking and learning.

> Understand and celebrate cultural diversity; understand the subject matter to be taught and be able to represent it in multiple ways pedagogically; reflect on the moral and ethical consequences of policy and classroom practice; engage in teaching as a shared responsibility; monitor student understanding and foster conceptual learning; engage learners in active, self-monitoring learning tasks; and relate experiences in school to critical issues in society. (p. 163)

In order to carry out this vision, teacher preparation, particularly in mathematics, must change. Wilson and Ball (1996) suggest three changes to teacher preparation: (a) sort out what components of teacher education must stay and what is unimportant, (b) provide models for prospective teachers of effective instruction, and (c) better prepare teachers to face the real complexities of teaching. In order to assess what prospective mathematics teachers needed from their preparation, Borko et al. (1992) examined the progress of middle school teachers through their final year of teacher preparation and their first year of teaching. They concluded that, "First, prospective teachers must be given the opportunity in their university coursework to strengthen their subject matter knowledge" (p. 219) and second, university coursework must provide prospective teachers the opportunity to develop "concepts and language to draw connections between representations and applications on the one hand and algorithms and procedures on the other" (p. 220).

## Secondary Teacher Preparation in Mathematics

According to the National Mathematics Advisory Panel (NMP) report of 2008, the effects of quality teaching account for 12%-14% of the total variability in student mathematics achievement on a yearly basis and the affect of effective or ineffective teaching compounds dramatically over multiple years. Hence, preparing candidates to teach mathematics well is essential. The development of mathematical knowledge is the first priority of mathematics teacher preparation programs. To develop the mathematical knowledge of teachers specifically for teaching, it is first vital to understand what that knowledge is. In an effort to build on Shulman's (1986) conceptualization of pedagogical content knowledge, Ball et al. (2008) proposed a practice-based theory of Mathematical Knowledge for Teaching. They sought to identify the specific knowledge mathematics teachers needed to do the work of teaching. Their conceptualization divided the domain into two large subdomains; pedagogical content knowledge and subject matter knowledge. They further subdivided pedagogical content knowledge into knowledge of content and student, knowledge of content and teaching, and knowledge of content and curriculum. They viewed subject matter knowledge as divided into three subdomains: specialized content knowledge, common content knowledge, and horizon content knowledge. Their conceptualization intends to reflect the intersection of mathematical knowledge and pedagogical knowledge and not the totality of knowledge needed for teaching, although they are unsure if the totality of teaching mathematics to students can ever be completely separated for the content (Ball, 2009).

The most common proxy for mathematical knowledge for secondary teachers is coursework, generally a major or minor in the subject or a subject examination, often

ETS's mathematics-specific Praxis Exam. The question becomes, however, is (and if so, how is) the knowledge teachers gain from either a major or minor in mathematics relevant to the teaching of mathematics? Research shows evidence that subject matter is important to teachers for increasing student achievement. However, much of the same research indicates that teachers with advanced knowledge in mathematics either have no effect or negative effect on students at lower levels of mathematics (e.g., Monk, 1994; Monk & King, 1994).

Ball et al. (2008) argue that although mathematical knowledge for teaching does include common content knowledge and horizon content knowledge, there is specialized content knowledge of mathematics that teachers need to know that others who study mathematics do not need to know. For example, a mathematician needs to know how to divide fractions, but a teacher not only needs to know how to divide fractions, but also why the "invert-and-multiply" algorithm works, how it is related to division of whole numbers, and how to create a concrete representation of the algorithm.

Using coursework as a proxy for mathematical knowledge may not be the best way to assess if a teacher has the mathematical knowledge for teaching identified by Ball et al. The Final Report of the National Mathematics Advisory Report (2008) found that,

> Although the amount of coursework or the possession of a degree in mathematics are both closer predictors of a teacher's mathematical knowledge than certification status, these are still both proxies for that knowledge and each has unique validity problems. Neither measures the actual command of specific mathematical topics and skills. Neither measures what an individual actually learned, which may vary substantially from person to person. There is similarly no information about the correspondence between particular courses and the school curriculum for which teachers are responsible. Thus, as a measure of the knowledge on which teaching depends, coursework or degree attainment may or may not correspond to what teachers use in the course of their work. (pp. 5-11)

In examining the seven studies that met their research parameters, the Task Group found that using mathematics college coursework as a proxy for teacher knowledge of mathematics may predict student achievement at and above $9^{th}$ grade where the content more closely matches college coursework. However, below $9^{th}$ grade, there was no evidence uncovered that supported the relationship. Further, the Task Group did not find research that met their criteria standard for preservice teacher preparation. They concluded that there is little research that unpacks the features of teacher training in mathematics that might account for a program's impact on teacher preparation. They recommended that more research in this area take place.

## Conclusion of Improving Student Access to Quality Teachers

Quality teachers matter greatly for student achievement in mathematics. Students in high poverty schools are least likely to have access to high quality teachers. A substantial reason for the lack of high quality teachers in high poverty schools is the so-called teacher shortage problem, particularly in mathematics. Though this dissertation is not focused on addressing teacher shortage issues, teacher shortage in mathematics does adversely affect access to quality teachers for students who most need them, and it is a concern. However, this dissertation is focused on how to best prepare and identify candidates for teaching mathematics before they enter the classroom. By better understanding the domains of teacher knowledge and skills for teaching mathematics, policy makers can better ensure that those entering the classroom, even with emergency credentials, are the best candidates for teaching. Further, interventions for teachers who are under or not qualified to teach mathematics can be better targeted if there is a fuller understanding of how novice teachers view their work and their preparedness to do it under the current structure.

The larger issue addressed in this section is how to better prepare all preservice teachers for the work of teaching mathematics, particularly for students of diverse backgrounds. The NMP's conclusion that course taking in mathematics may be problematic as a proxy for mathematical knowledge for teaching is a significant indicator that research on the effectiveness of college coursework in mathematics on teacher knowledge for teaching is needed. Additionally, conclusions drawn by Ball et al. (2008), Borko et al. (1992), Howey (1996), Kennedy (1999), and Wilson and Ball (1996) indicate that teacher preparation structures need to be reworked to address our changing understanding of what the work of teaching is, how we have come to understand student learning, and to reflect the diversity of today's learners.

I propose that there is a general disconnect between what teacher preparation programs believe preservice teachers need in order to do the work of teaching mathematics and what novice teachers believe they need and what they received as they entered teaching. The research questions in this dissertation attempt to ascertain if indeed there is a disconnect, and if so, where that disconnect lies.

## Student Achievement in Mathematics

Student demographics have changed substantially in the last 30 plus years in the United States. According to the National Center for Education Statistics, *Trends Among High School Seniors*, in 1972 86% of the senior population was White. By 2004 Whites accounted for 62% of high school seniors. During that same time period, the percentage of Hispanic students increased from 4% to 15%, and the percentage of Black students increased from 5% to 14%.

The report also notes that many positive strides in mathematics education have occurred since the 1970s. For example, the percent of seniors taking Calculus increased form 6% in 1982 to 13% in 2004, and the percent of seniors taking no math class decreased from 57% to 34% over the same time period. However, when senior mathematics course taking is disaggregated by ethnicity, the picture is less encouraging. In 2004, 27% of Asian students took advanced mathematics courses, versus 4% of Black students, 6% of Hispanic students, and 15% of White students.

Another indication that mathematics education may be showing signs of improvement comes from the *NAEP 2008 Trends in Academic Progress* report, which reveals that for all three age groups (9-, 13-, and 17-year-olds), scores in mathematics have improved since 1973. When data are disaggregated by student ethnicity, it reveals that Black students made greater gains since 1973 than did White students. For 9-year-olds, there was an increase of 34 points for Black students and 25 points for White students. Thirteen-year-old Black students gained 34 points and 13-year-old White students gained 16 points. Seventeen-year-old Black students increased by 17 points and 17-year-old White students gained 4 points. There was, however, no significant change in the achievement gap between Black students and White students between 2004 and 2008. Hispanic students also made greater gains than White students since 1973: an increase of 32 points for 9-year-olds, 29 points for 13-year-olds, and 16 points for 17-year-olds. As with the achievement gap between Black students and White students since 2004, it has not changed since 1973 between Hispanic students and White students.

It is important to note that for White, Black, and Hispanic students, the greatest gains in scores are for the younger ages. In other words, there were the greatest gains for 9-year-olds and the smallest gains for 17-year-olds. This trend holds true for all ethnicities. The NAEP points out that higher scores are associated with higher levels of mathematics course taking. For 13-year-olds, the highest scores were correlated to students who had taken Algebra. For 17-year-olds the highest scores were correlated to students who took Pre-Calculus or Calculus.

Given that high school course taking trends indicate that more students are taking mathematics as seniors, and they are taking more rigorous coursework, evaluating student progression in mathematics may be essential in understanding why 17-year-old students are not seeing the same achievement gains as 9- and 13-year-old students. In other words, if course taking is correlated to student achievement, why are not more students taking higher levels of mathematics as seniors, particularly given that they seem to be doing better in the lower grades?

In Utah, course taking patterns reveal that students drop out of the trajectory in which students started in 7$^{th}$ grade at alarming rates. According to the Utah State Office of Education (USOE), for students who were in 7$^{th}$ grade in 2005 who started in Math 7, 82% went on to Pre-Algebra in 8$^{th}$ grade, 74% went on to Algebra in 9$^{th}$ grade, 52% went on to Geometry in 10$^{th}$ grade, and 37% went on Algebra II in 11$^{th}$ grade. For students who started in Pre-Algebra in 7$^{th}$ grade for the same cohort, 76% went on to Algebra in 8$^{th}$ grade, 59% went on to Geometry in 9$^{th}$ grade, 55% went on to Algebra II in 10$^{th}$ grade, and 39% went on to Pre-Calculus in 11$^{th}$ grade. Finally, for the students that started in Algebra in 7$^{th}$ grade for the same cohort, 76% went on to Geometry in 8$^{th}$ grade, 71% went on to Algebra II in 9th grade, 63% went on to Pre-Calculus in 10th grade, and 44% went on to Calculus in 11th grade. What these data reveal is that students progressively drop out of their trajectory at each consecutive grade.

Student proficiencies may reveal part of the reason. For the 2006-2007 academic year, for example, state proficiencies were 76% for 3rd grade math, 78% for 4th grade math, 77% for 5th grade math, 79% for 6th grade math, 69% for Math 7, 78% for Pre-Algebra, 72% for Algebra, and 68% for Geometry. In 2009 when the state examined the new core, proficiencies were 69% for 3rd grade math, 72% for 4th grade math, 72% for 5th grade math, 67% for 6th grade math, 65% for Math 7, 64% for Pre-Algebra, 49% for Algebra, and 61% for Geometry (Algebra II proficiencies were assessed, but because results were so poor, the USOE elected to not report them as part of Annual Yearly Progress).

In Utah, however, as in many other states, students are placed in 7th grade mathematics courses based on varied measures of student achievement in elementary school. Ostensively then, students entering a 7th grade math class should be ready for the class in which they are enrolled. This is not the case for elementary mathematics wherein students are promoted strictly based on their grade level. Hence, students placed in Algebra in 7th grade are those students that have been identified as being ready for Algebra by their school district or school system. Why then do only 76% move on to Geometry? Further, if we assume placement in a course is a proxy for preparedness for a course, why do we continue to see drops in students moving on to the next course?

The answer is likely twofold. On the one hand, proficiencies indicate that many students are likely not ready to move on to the next class in mathematics at each juncture of progression. On the other hand, teachers and teaching play a role in how successful students are in achieving proficiency. Taken together, we see that as students finish one course, many are not ready to move on to the next, and therefore repeat the class. However, those that do not repeat are presumed prepared to take the next class. For those students who are prepared to move on to the next class, several factors play into achievement. How many of those factors teachers are able to govern is a matter of debate in the educational community. However, if the NMP is correct that 12%-14% of student achievement is attributable to the teacher, then we know that the quality of the teacher plays at least a role in why students are not ready to move on in mathematics.

Although there is evidence of increase in student achievement in mathematics across the country, we are not seeing the same kind of increase at the secondary level that we are seeing at the elementary level. We know that between 12%-14% of student achievement in mathematics is attributable to teachers and that effects compound over time. There is evidence that students are not going on to higher levels of mathematics because they are not ready for the next class, even though they were likely ready for their current class.

If policy makers reevaluate teacher preparation and licensure to ensure that only those that are best prepared to do the work of teaching mathematics enter the classroom, then perhaps we will see a decrease in the number of students dropping out of the trajectory on which they start in 7th grade. This may then result in more students taking high-level mathematics in high school.

## Conclusions from Literature Review

The literature reviewed herein is the foundation on which the conceptual framework for this dissertation rests. My perspective is to ensure that only those best prepared to become teachers of mathematics enter the classroom. To that end, I have laid out research in teacher quality, teacher licensure, improving student access to quality teachers, mathematics teacher preparation, and student achievement in mathematics.

Research on teacher quality indicates that teacher subject matter knowledge and licensure are indicators of student achievement. In terms of subject matter knowledge, using coursework as a sole proxy for subject matter knowledge may be problematic in that we know that for mathematics, some coursework is associated with student achievement but higher levels of college mathematics coursework may not be. Further, there is indication in the research that teachers may not be getting the kind of mathematical knowledge they need for teaching. Hence, studying how teachers view their preparedness to teach mathematics and their perceptions of where they learned their skills and knowledge may help to inform policy makers of how to improve teacher preparation in terms of content.

In terms of licensure, the two domains of teacher knowledge on which licensure tends to focus are content and pedagogical knowledge. I make two arguments on this point. First, I argue that the domains of content and pedagogy that frame licensure are not clearly focused on what teachers need to know and be able to do in order to do the work of teaching. Second, I propose that these two domains are not sufficient to address the fullness of how novice teachers view their work. To address both these points, I have offered, through the framework proposed, four domains under which I argue novice teachers see their work and definitions of those domains that more clearly articulate the work of novice teachers. Thus, the purpose of the study is to investigate the validity of the framework offered.

The research on student access to quality teachers underscores the importance of addressing teacher preparation in mathematics. Students in high poverty schools are the most likely to not have high quality, well-qualified teachers. The needs of these students must be addressed in teacher preparation to ensure that all students have equitable access to higher levels of mathematics.

The research on teacher preparation in mathematics reveals the possible disconnect between the mathematics studied in college and the mathematics teachers must be able to do when working with learners at the secondary (and even elementary) level. The preponderance of the research points to teachers being able to do mathematics, but not necessarily being able to teach it. Here again, the research points to a need to better understand, from the perspective of the novice teacher, how well teacher preparation programs are training prospective teachers to do their work.

Lastly, the research reviewed regarding student achievement in mathematics across the country, and specifically in Utah, shows that although there has been improvements in student achievement in mathematics within the last 30 years, students at the secondary level are not improving at the same rate as students at the elementary level. Additionally, there is strong evidence that students are dropping out of mathematics at alarming rates. Improving the quality of instruction may help in decreasing the number of students repeating courses or dropping out of mathematics.

I propose that there are four domains under which knowledge and skills of teaching mathematics fall: mathematical (content) knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge. The purpose of this dissertation is to first, investigate the validity of the conceptual framework from the perspective of novice teachers. Second, it is to examine the extent to which novice teachers feel they are prepared to do the work of teaching. Third, it is to investigate where novice teachers believe they gained the knowledge and skills they have in teaching mathematics. Fourth, it is to ascertain if teachers report discernable differences in their preparation programs. Results of this research may inform policy around both mathematics teacher preparation and teacher licensure.

CHAPTER 3

# DESIGNING A METHOD FOR INVESTIGATING NOVICE TEACHER PERCEPTIONS OF PREPARATION

This study seeks to examine the extent to which novice secondary mathematics teachers perceive they are prepared to do the work of teaching secondary mathematics. Specifically, it seeks to determine if novice secondary mathematics teachers' perceptions of their knowledge and skills of doing their work of teaching secondary mathematics falls in the four domains proposed by the framework: pedagogical knowledge, mathematics knowledge, pedagogical content knowledge, and curricular knowledge and how well prepared they feel in each of those domains. Additionally, it seeks to examine where (college coursework, student teaching, or experiences outside of college) novice mathematics teachers believe they gained the skills and knowledge to do the work of teaching secondary mathematics. Lastly, I seek to determine if novice teachers from different preparation programs in Utah report a difference in their perceptions of preparedness. These issues are relevant to mathematics teacher preparation and hence may inform policy.

## Research Questions

Four questions frame the research of this dissertation:

1. Do novice secondary mathematics teachers' perceptions of their

knowledge and skills in the work of teaching fall into four domains: mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge?

2. To what extent do novice teachers perceive they are prepared to do the work of teaching secondary mathematics?
3. Where do novice mathematics teachers report they gained their knowledge and skills for teaching?
4. Do novice mathematics teachers prepared in Utah institutions report any differences in their knowledge and skills for teaching secondary mathematics?

## Participants

Data for this study were collected via an electronic survey instrument developed by me specifically for the purposes of this research. A query conducted through the Utah State Office of Education using the 2008-2009 CACTUS database identified teachers who met the desired sample criteria specifically, teachers new to the teaching of mathematics (within the last 5 years). The term *Novice Teacher* refers to teachers with 5 or less years of total teaching experience. The duration of 5 years was somewhat arbitrarily chosen in that there is no steadfast period of time in the literature that typically identifies the duration of time it takes for a teacher to move from "novice" to "experienced." The query also identified all teachers actively teaching in the 2008-2009 academic year who had a current teaching assignment in secondary mathematics excluding Math Grade 6 and any Special Education Mathematics codes. The code for Math Grade 6 was excluded because in Utah, the secondary mathematics core curriculum begins with Math 7. Special Education Mathematics codes were eliminated because Special Education Mathematics classes are not well defined in mathematical content in that they do not have Utah State Core Curriculums.

School email addresses were obtained for each teacher identified by the query using the USOE school district directory or by contacting individual schools. I contracted with the Utah Education Policy Center (UEPC) to administer and collect data for the survey. On February 2, 2009, the UEPC sent an email invitation (see Appendix C) to participate in the research study via email using Snap 9 Professional, an electronic survey instrument. The body of the email contained information about the research project and invited recipients to enter the survey (see Appendix A). A weekly reminder was sent to those that had not completed the survey. A total of four reminders were sent by the close of the survey on March 2, 2009.

Of the 562 surveys sent out, 142 were opened and at least partially completed. I excluded respondents with more than 5 years experience from the sample because they did not fit the research criteria. Surveys that were less than 95% complete were also excluded because constructs would have to be created by collapsing data; hence, missing data would be problematic. Eliminating respondents that had been teaching for more than 5 years and those that had completed less than 95% of the survey left 95 completed surveys for the study. Data from the survey were exported into the Statistical Package for the Social Sciences (SPSS) and all statistical analysis was run with this program. Table 1 describes the demographic representation of the study participants.

Table 1

Demographics of Participants

| Variable | | N | Percent |
|---|---|---|---|
| Gender | | | |
| | Male | 35 | 36.8% |
| | Female | 59 | 62.1% |
| | Not Reported | 2 | 2.1% |
| Licensure Status | | | |
| | Licensed | 88 | 92.6% |
| | Not Licensed | 7 | 7.4% |
| Years of Mathematics Teaching Experience | | | |
| | 1st Year | 20 | 21.1% |
| | 2nd Year | 19 | 20% |
| | 3rd Year | 22 | 23.2% |
| | 4th Year | 18 | 18.9% |
| | 5th Year | 16 | 16.8% |
| Level of Mathematics Endorsement | | | |
| | Level II | 8 | 8.4% |
| | Level III | 13 | 13.7% |
| | Level IV | 63 | 66.3% |
| | Does Not Know | 3 | 3.1% |
| | No Endorsement Yet | 8 | 8.4% |
| School District/Charter School | | | |
| | Alpine | 10 | 10.5% |
| | Granite | 10 | 10.5% |
| | Davis | 6 | 6.3% |
| | Jordan | 22 | 23.2% |
| | Nebo | 6 | 6.3% |
| | Tooele | 7 | 7.3% |
| | Washington | 5 | 5.3% |
| | Other Public School District | 29 | 30.5% |
| | Charter School | 9 | 9.5% |
| Institution from which Licensure was Earned | | | |
| | Brigham Young University | 23 | 24.2% |
| | Southern Utah University | 10 | 10.5% |
| | University of Phoenix | 3 | 3.1% |
| | University of Utah | 12 | 12.6% |
| | Utah State University | 13 | 13.7% |
| | Utah Valley State (College) University | 3 | 3.1% |
| | Weber State University | 4 | 4.2% |
| | Western Governors University | 1 | 1.1% |
| | Other | 15 | 15.8% |
| | No Licensure yet | 7 | 7.4% |
| | Missing | 4 | 4.2% |

Thirty-five of the respondents were male (36.8%), 59 were female (62.1%), and 3 participants did not identify gender. For the population of 562 novice mathematics teachers, 40.7% were male and 59.1 % were female. Chi-square goodness of fit test revealed that the sample population did not differ significantly from the 562 in terms of gender, $X^2$ (1, N=92)=.551, $p$=.458. Twenty respondents were in their first year of teaching mathematics, 19 in their second, 22 in their third, 18 in their fourth, and 16 in their fifth year. Eight had a level 2 mathematics endorsement, 13 a level 3 mathematics endorsement, 63 a level 4 mathematics endorsement, 3 did not know what level they had, and 8 had not yet received a mathematics endorsement at the time of the survey. Teachers from 22 of the 40 Utah public school districts responded. Additionally, 9 teachers from charter schools responded. Representation from Jordan School District was particularly high: 23.7% of the respondents, likely because I work in that district. However, each of the other largest districts had proportionally high response rates: Alpine, 10.3%; Granite, 10.3%; Davis, 6.2%; Nebo, 5.2%; Tooele, 6.2%; and Washington, 5.2%.

## Instrument

I created the survey to examine the research questions (see Appendix A for the full survey). Data gathered from Parts I and III of the survey were used to answer the research questions. Part I of the survey investigated novice teachers' sense of preparedness to do the work of teaching secondary mathematics. Part III gathered demographic information of participants.

Part I (Questions 1-34)

Each item in Part I represented a discrete skill or concept involved in the teaching of secondary mathematics. Examples of items in Part I include the following: "modify curriculum to meet the need of English language learners," "explain simplification rules such as why $\sqrt{(x+y)^2}=(x+y)$ but that $\sqrt{(x^2+y^2)}\neq(x+y)$ in a manner that is accessible to secondary students," or "help students use prior mathematical understandings to build new understandings, i.e., help students connect adding simple fractions to adding algebraic fractions." Each item required respondents to answer two questions. Question A was "How well prepared are you with respect to the knowledge or skill items listed below?" and Question B was "Where did you PRIMARILY learn each of the knowledge or skill items listed below?" For Question A, the participant was given a Likert-type scale with four levels: (a) not at all prepared, (b) somewhat prepared, (c) well prepared, and (d) very well prepared. For the second question, the participant was given seven nominal choices: (a) in my college **math** classes, (b) in my college general **education or licensure** classes, (c) in my college **math methods or pedagogy** classes, (d) during my **student teaching** experience, (e) from my own **personal experiences** (e.g., as a student or tutor), (f) during my initial **teaching** experience, and (g) other; please specify.

Items for Part I were adapted or designed to evaluate teacher perceptions of their preparation to do the work of teaching secondary mathematics. Each question in Part I of the survey was written to correspond to one of the four domains of teacher preparation proposed in the conceptualization: pedagogy (pedagogical knowledge), mathematics (content knowledge), mathematics pedagogy (pedagogical content knowledge), and curriculum (curricular knowledge). Survey items in the pedagogy and curricular domain were adapted fairly closely from the Utah Novice Teachers Research Team (2008) and Darling-Hammond et al. (2002). Items corresponding to pedagogical content knowledge were more substantially altered in adaptation from the same authors as well as written to match the proposed framework as it builds from the work of Ball et al. (2008), Hill et al. (2005), and Shulman (1986). Items in the mathematical (content knowledge) domain where written to align with the construct of mathematical content knowledge developed for this study, which also builds on the work of Ball et al. and Hill et al..

Part III (Questions 55-70)

Part III of the survey asked demographic information of participants including items related to age, gender, race or ethnicity, institution(s) from which the participant earned degree(s) and license, type(s) of degree, highest degree, years of experience, level of endorsement, grades subject participant teaches, subjects and number of sections taught, and school district or charter or private school.

Variables for the Study

Several variables were created to measure constructs central to the analysis herein. A complete description of procedures for creating each of the variables follows in the next section. Refer to Appendix D for specific items from the survey that composed each created variable. Three variables were created from data collected from the survey.

a. Four teacher knowledge and skill domain variables: mathematical knowledge (content knowledge), pedagogical knowledge, pedagogical content knowledge, and curricular knowledge.

b. Teacher perceptions of where they learned each of the four teacher knowledge and skill domain variables: in college, during student teaching, or after college.

c. Teacher demographic information: institution from which teaching licensure was earned and level of mathematics endorsement.

The specific steps involved in creating each variable are outlined below.

Four Teacher Knowledge and Skills Domain Variables

Each item from Question A of Part I of the survey was written to correspond to one of the four conceptualized domains proposed by this research. Items correlating to Mathematical Knowledge asked participants to evaluate their knowledge and skills around specific mathematical tasks and ideas such as "explain why multiplication involving two fractions renders a product smaller than both factors" or "explain simplification rules such as why $\sqrt{(x+y)^2}=(x+y)$ but that $\sqrt{(x^2+y^2)}\neq(x+y)$ in a manner that is accessible to secondary students." Items correlating to Pedagogical Content Knowledge asked participants to evaluate their knowledge and skills around pedagogy specifically linked to mathematics such as "help students move from concrete understandings of mathematics to abstract understandings, i.e., teach student how to draw pictures of problem situations and then use the picture to write a mathematical expression or equation for the problem" or "help students use prior mathematical understandings to build new understandings, i.e., help student connect adding simple fractions to adding algebraic fractions." Items corresponding to Pedagogical Knowledge asked participants to evaluate their knowledge and skills around content neutral pedagogy such as "address the needs of students who receive special education services" or "modify curriculum to meet the need of English language learners." Items corresponding to Curricular Knowledge asked participants to evaluate their knowledge and skills around using standardized curricula such as "use the standards and objectives of the Utah State Core Curriculum in selecting curriculum to use for instruction" or "use the state's core curriculum and performance standards to plan instruction." For a complete list of items and their intended construct, see Appendix D.

Teachers evaluated their level of knowledge and skill on each of the items using a four-level Likert-type scale (1=not at all prepared, 2=somewhat prepared, 3=well prepared, 4=very well prepared). Using these items, I conducted a principal axis factor analysis with varimax rotation where missing values were replaced by the mean. Of the seven factors that emerged, four were used in this analysis (Chapter 4 contains a complete description of the factor analysis procedures used). Items for each of the factors was then combined to form the four construct variables by finding the numeric mean of the items within the construct. The value of the new variable thus represents a mean score of how well prepared the respondent feels she or he is relative to the items in the construct.

Where the Knowledge was Learned Variables

Respondents were also asked in Question B of Part I where they learned the knowledge or skill identified by each item. Respondents were give seven choices: (a) in my college math classes, (b) in my college education and licensure classes, (c) in my college math methods and pedagogy classes (d) during my student teaching experience, (e) from my own personal experiences (e.g., as a student or tutor), (f) during my initial teaching experience, and (g) I am working on learning this skill. Choices a, b, and c were collapsed into "in college," choice d was labeled "student teaching," choices e and f were collapsed into "outside of college," and g was labeled "other." Then, each item was recoded into three dummy variables corresponding to where the respondent indicated they learned the knowledge: "in college," "student teaching," or "outside of college." Finally, items corresponding to "in college" for each of the knowledge constructs (mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge) were combined together and the numeric mean was calculated. This was also done for "student teaching" and for "outside of college" as well. Hence, for each knowledge construct there is an "in college," "student teaching," and "outside of college" score. The score for each reflects the average percent knowledge gained in college, student teaching, or outside of college for each construct.

Demographic Variables

Responses to "what level of math endorsement do you hold" were used for analysis in research question 2. Responses for "where did you earn your secondary teaching license" were recoded into a variable that included only the four institutions from which most of the respondents received their licensure (see Table 2). These four institutions, Brigham Young University (*N*=23), Southern Utah University (*N*=10), University of Utah (*N*=12), and Utah State University (*N*=13), comprised 61% of the responses. Not included in this variable were 15.8% of respondents that cited "Other" for where they earned their licensure, 11.3% that cited four other Utah institutions, and 7.2% that had not yet earned their secondary licensure. I decided not to include the four other Utah institutions above (representing 11.3% of the respondents) because the size of each of the groups was four or less (University of Phoenix [*N*=3], Utah Valley State University

[*N*=3], Weber State University [*N*=4], and Western Governors University [*N*=1]). Additionally, respondents who earned their degree outside of Utah were not included in the study. This variable was used to answer research question 4.

## Analysis

To answer research question 1 (*Do novice secondary mathematics teachers' perceptions of their knowledge and skills in the work of teaching secondary mathematics fall into the four proposed conceptualized domains: mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge?),* I conducted an exploratory principal axis component factor analysis using a Varimax rotation with Kaiser Normalization to investigate the construct validity of the four domains of teacher preparation (see Chapter 4 for a complete description of the factor analysis.) Cronbach's Alpha was employed to evaluate the internal consistency of the factors that emerged. The factors that emerged from research question 1 were then used for subsequent research questions.

To answer research question 2 (*To what extent do novice teachers perceive they are prepared to do the work of teaching secondary mathematics?),* several statistical tests were employed. First, I investigated the extent to which all participants felt prepared in each of the four domains that emerged from research question 1 (mathematical knowledge, pedagogical content knowledge, pedagogical knowledge, and curricular knowledge) by finding the numeric mean and standard deviation for each. I then conducted bivariate correlations and a repeated measures ANOVA for the constructs. As part of the repeated measures ANOVA, I also investigated pairwise comparisons of each type of knowledge. Finally, I conducted a one-way ANOVA with level of endorsement as an independent variable to evaluate if there was a difference means for knowledge by level of mathematics endorsement.

To evaluate research question 3 (*Where do novice mathematics teachers report they gained their knowledge and skills for teaching secondary mathematics?*), data from Question B of Part I were collapsed into three categories: *College*, *Student Teaching*, and *In-Service* (as described above) for each of the domains (mathematical knowledge, pedagogical content knowledge, pedagogical knowledge, and curricular knowledge). I found mean percents for the amount of knowledge respondents perceived they gained in college, student teaching, and outside of college for each of the four domains. I then conducted paired *t*-tests to evaluate the differences in the mean percents.

To answer research question 4 *(Do novice mathematics teachers who were prepared at different Utah institutions report any differences in their knowledge and skills for teaching mathematics at the secondary level?)*, I used the institution variable created for this question as the factor and the four knowledge domains as the dependent variables to conduct a one-way ANOVA to investigate the differences in the means for respondents' sense of preparedness by institution.

## Conclusion

The methods employed in this research are designed to investigate the validity of the proposed construct of novice teacher knowledge and the extent to which teachers feel prepared to do the work of teaching as they transition from "expert student to novice teacher." Further, the methods employed herein seek to inform educational policy around teacher preparation. Understanding how well prepared novice teachers feel to do all aspects of their work will help teacher preparation programs better fit training programs to the needs of future mathematics teachers. The chapter that follows will describe the results of the methods outlined in this chapter.

# CHAPTER 4

# NOVICE SECONDARY TEACHER PERSPECTIVES OF THEIR PREPAREDNESS TO TEACH MATHEMATICS

The analysis of the research questions was conducted in two phases while following the order of the research questions. The first phase dealt with the evaluation of the proposed conceptual framework for novice teacher knowledge and the formation of the variables that coincided with components of the framework. The second phase dealt with using the framework and associated variables in evaluating the remaining three questions. An alpha level of .05 was used for all statistical tests.

## Phase One: Evaluating the Proposed Framework of Novice Mathematics Teacher Knowledge

Phase one of the research comprised the evaluation of the proposed framework. Typically, the description of a factor analysis conducted for a study is provided primarily in the methods section of research write-ups. However, because the framework proposed by this research is central to the investigation herein, the description of the investigation conducted by the factor analysis and its results are described below.

## Research Question 1

*Do novice secondary mathematics teachers' perceptions of their knowledge and skills in the work of teaching fall into the four proposed conceptualized domains: mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge?* An exploratory factor analysis was conducted on all items from Part I of the survey. Items from this portion of the survey corresponded to skills and knowledge associated with the work of teaching secondary mathematics as outlined by the proposed conceptual framework (see Appendix A). Seven factors with eigenvalues greater than one emerged from the factor analysis (see Appendix E). Those seven factors account for 61.91% of the variance.

### Elimination of Items

Only items with rotated factor loads greater than .4 were considered. Item 21 from the survey did not load greater than .4 on any factor and was thus deemed a poor item and was eliminated from the set of items. Additionally, items that loaded greater than .4 on more than one factor but within .1 of another factor were eliminated. Such items were 1, 2, 5, 10, 14, and 15 and were thus all eliminated. Lastly, items that did not fit well conceptually within a factor were eliminated. Items 4 and 23 were the only two items to load on factor 5 but they did not fit conceptually well together, so they were eliminated. Item 3 loaded on factor 2, but it was eliminated because it did not fit conceptually well with the other items in the factor. Hence, a total of 10 items were eliminated by this process.

Elimination of Factors

Factors 5-7 were problematic. Issues with these factors stemmed from two facts. First, factors 5-7 loaded with only one or two each. More specifically, factors 5 and 7 had two items each and factor 6 only had one item. Hence, it was difficult to evaluate the conceptual construct within these factors. Second, most of the items within factors 5-7 were eliminated based on the research decision rules stated above.

As was discussed in the previous section, only two items loaded on factor 5: items 4 and 23. Though the two items passed both the test of loading greater than .4 and more than .1 above the next highest load on the item, they did not fit conceptually well together; hence, they were both eliminated and therefore left no items in factor 5. Thus, factor 5 was eliminated.

Item 14 was the only item that loaded on Factor 6. As was discussed above, its load was less than .1 from another factor for the item, so it was deemed a poor item and thus eliminated. Hence, as with factor 5, there were no items for factor 6 and factor 6 was eliminated.

Two items loaded on factor 7, items 2 and 5, but (as was discussed above) both items loaded within .1 of other factors and were thus eliminated. Hence, as with factors 5 and 6, there were no items within the factors and therefore factor 7 was eliminated.

In summation, 11 items were eliminated. Of these 11 items, 5 were items in factors 5-7, which ultimately resulted in the elimination of factors 5-7. Because of the problems associated with factors 5-7 and the strong relationship between factors 1-4 and the four hypothesized domains of teacher knowledge, only factors 1-4 were used on the subsequent analysis. These four factors accounted for 50.52% of the variance. The remainder of the factor analysis procedure followed is described below.

## Four Factors Representing Domains of Novice Mathematics Teacher Knowledge

### Mathematical Knowledge

Each item identified in factor 1 is listed in Table 2 with its load and the construct under which I originally thought it fit. Each of the items in this factor identifies a specific mathematical concept. In addition, each item herein contains the verb "explain" or "prove" but not the verb "teach." Hence, the items within Mathematical Knowledge relate to *knowing* or *doing* specific mathematical tasks but not to the ability to *impart* that knowledge on another. Items in this factor are unique in two ways: (a) each item identifies specific mathematical skills and knowledge directly associated with mathematical content at the secondary level; and (b) each item asks the respondent if they are able to explain or prove these specific mathematical concepts, but not teach them or impart them to the student. Hence, the analysis indicates that novice teachers respond more uniquely when the verb "teach" is absent in an item related to specific mathematical content than they do when asked about connecting students to general mathematics concepts. This factor is consistent with the Mathematical Knowledge construct as defined in the framework in Chapter 1 and is therefore labeled Mathematical Knowledge.

### Pedagogical Content Knowledge

Each item identified in factor 2 is listed in Table 3 with its load and the construct under which I originally thought it fit. The items in this factor created the Pedagogical

Table 2

Factor 1 Items

| Item | Load | Original Construct |
|---|---|---|
| 22. Explain the algorithm of "invert and multiply" for dividing fractions to students both pictorially and numerically. | .476 | PCK |
| 24. Explain simplification rules such as why $\sqrt{(x+y)^2}=(x+y)$ but that $\sqrt{(x^2+y^2)}\neq(x+y)$ in a manner that is accessible to secondary students. | .772 | PCK |
| 25. Explain mathematics symbols in a manner that helps students understand their mathematical meaning, i.e., helping students understand the difference between 2x, $x^2$, and $2^x$. | .755 | PCK |
| 26. Explain why multiplying two negative numbers renders a positive product. | .510 | MK |
| 27. Explain the algorithm for an integral using area. | .709 | MK |
| 28. Explain the relationship between area models for multiplication, the standard algorithm for multiplication of multi-digit numbers, and the distributive property. | .709 | MK |
| 29. Explain why multiplication involving two fractions renders a product smaller than both factors. | .714 | MK |
| 30. Prove the quadratic equation. | .747 | MK |
| 31. Explain the difference between polynomial and exponential functions. | .826 | MK |
| 32. Explain graphing transformation rules (why does f(x-h)+k the graph of f(x) k vertically and h horizontally). | .753 | MK |
| 33. Explain why one would want to convert rectangular coordinates to polar coordinates or polar coordinates to rectangular coordinates. | .673 | MK |
| 34. Prove fundamental trigonometric identities ($1+\tan^2x=\sec^2x$). | .804 | MK |

Table 3

Factor 2 Items

| Item | Load | Original Construct |
|---|---|---|
| 16. Take into account students' prior understandings about mathematics when planning curriculum and instruction. | .597 | PCK |
| 18. Help students move from concrete understandings of mathematics to abstract understandings, i.e., teach student how to draw pictures of problem situations and then use the picture to write a mathematical expression or equation for the problem. | .679 | PCK |
| 19. Help students use prior mathematical understandings to build new understandings, i.e., help student connect adding simple fractions to adding algebraic fractions. | .577 | PCK |
| 20. Help students use comprehension strategies in mathematics to understand problems and make predictions. | .556 | PK |

Content Knowledge variable. Each of the items herein relates to the *teaching* of *general* mathematics. Items 18, 19, and 20 specifically use the phrase "help students" in terms of mathematics, while item 16 asks the respondent about their ability to "take into account" students in planning and instruction. Further, none of the items identifies specific mathematical skills. Hence, these items are different then those in the Mathematical Knowledge factor in two ways: (a) they relate to imparting or connecting students to mathematics, and (b) they do not identify specific mathematical skills or knowledge--rather they identify mathematics in general terms. Specifically, the Mathematical Knowledge factor addresses the ability to explain or prove specific mathematical knowledge while this factor relates to the ability to tie general mathematical knowledge to the student either by helping the student understand the content or by taking into account the students in planning and instructing. These items relate directly to the definition offered for pedagogical content knowledge from the original framework and thus I used these items to construct the Pedagogical Content Knowledge variable.

Pedagogical Knowledge

Each item identified in factor 3 is listed in Table 4 with its load and the construct under which I originally thought it fit. I used all four items that loaded on this factor to construct the Pedagogical Knowledge variable. None of the items in this factor mention mathematics and all specifically identify meeting the needs of learners with special needs. The skills identified in this factor are general teaching skills that all teachers need and are not associated with mathematics specifically. This factor is therefore different then both Mathematical Knowledge and Pedagogical Content Knowledge in that (a) there is no mention of mathematics, specific or general, in the items; and (b) the skills and knowledge identified in each item are skills and knowledge that all teachers, regardless of content, must have. Therefore, this factor corresponds to Pedagogical Knowledge as defined in the original framework.

Table 4

Factor 3 Items

| Item | Load | Original Construct |
|---|---|---|
| 6. Modify instruction, practice, dialog, and assessment for learners who require special education accommodations. | .633 | PK |
| 7. Modify curriculum to meet the needs of English language learners. | .465 | PK |
| 8. Identify and address special learning needs or difficulties. | .756 | PK |
| 9. Address the needs of students who receive special education services. | .721 | PK |

Curricular Knowledge

Each item identified in factor 4 is listed in Table 5 with its load and the construct under which I originally thought it fit. Each of the items in this factor asks the participant about their ability to "use" state or national educational tools for instruction. Items 12 and 13 specifically ask about the respondents' ability to use the State Core Curriculum to guide instruction, while item 17 refers to standardized assessments. These items are different from the other three domains in that (a) they do not identify mathematical content, either specific or general; (b) they relate to standard educational tools that mathematics teachers should use in planning instruction; and (c) they do not relate to teaching specific populations of students. These items fit with the original framework of Curricular Knowledge and were combined to create the Curricular Knowledge variable.

Once I identified the four domains under which novice teachers' perspectives of their preparedness load, I combined the items corresponding to each construct by taking the mean of all associated items and employed Cronbach's Alpha to evaluate the internal consistency of each domain. For each of the four domains, $\alpha > .8$ with alphas ranging

Table 5

Factor 4 Items

| Item | Load | Original Construct |
|---|---|---|
| 12. Use the standards and objects of the Utah State Core Curriculum in selecting curriculum to use for instruction. | .845 | CK |
| 13. Use the state's Core Curriculum and performance standards to plan instruction. | .842 | CK |
| 17. Use standardized mathematics assessments to guide your decision about what skills, concepts, and processes to teach. | .604 | PCK |

from .806 to .939, indicating that there is strong internal consistency for each construct (see Table 6). Hence, the combination of these two tests, the exploratory factor analysis and Cronbach's alpha, offers evidence of both the instrument's reliability and validity for assessing the four domains proposed by the conceptual framework for secondary mathematics teachers' work. The four domains; mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge, are the domains that will be used to answer the remaining research questions.

## Phase Two: Use of Conceptual Framework in Understanding Secondary Mathematics Teacher Preparation

The second phase of the research focused on applying the proposed framework validated in research question 1 to understanding teachers' sense of preparedness to do the work of teaching secondary mathematics. First, I evaluated how well teachers felt prepared in each of the domains of the framework. Then, I examined where novice teachers believe they gained the skills and knowledge for teaching secondary mathematics as defined in each of the domains. Finally, I investigated if novice teachers

Table 6

Cronbach's Alpha for each Construct

| Construct | Cronbach's Alpha |
|---|---|
| Mathematical Knowledge | .94 |
| Pedagogical Content Knowledge | .86 |
| Pedagogical Knowledge | .81 |
| Curricular Knowledge | .89 |

report a discernable difference in their perception of preparedness relative to where they earned their secondary teaching license.

## Research Question 2

*To what extent do novice teachers perceive they are prepared to do the work of teaching secondary mathematics?* In order to determine how well novice teachers felt prepared to do the work of teaching secondary mathematics, I found the mean of the four domains of knowledge identified in research question 1. Respondents were asked to rate "how well prepared" they felt with respect to each knowledge or skill identified by the items in Part I of the survey. Respondents were given a 4-level Likert-type scale with which to respond (1=Not at all prepared, 2=Somewhat prepared, 3=Well prepared, 4=Very well prepared). Items from this section were collapsed into the four domains identified by research question 1 and the arithmetic mean of the responses was computed. Means and standard deviations for each of the variables are displayed in Table 7.

The results of the analysis seem to indicate that of the four domains of skills and knowledge of mathematics teaching, novice teachers feel most prepared in the domain of

Table 7

Means for Domains of Secondary Mathematics Teacher Knowledge

| Construct | Mean | *SD* |
|---|---|---|
| Mathematical Knowledge | 2.66 | .74 |
| Pedagogical Content Knowledge | 2.53 | .68 |
| Pedagogical Knowledge | 2.10 | .60 |
| Curricular Knowledge | 2.54 | .81 |

mathematical knowledge, with a mean score of 2.66, and least prepared in the domain of pedagogical knowledge, with a mean score of 2.10. Mean scores for pedagogical content knowledge and curricular knowledge were relatively close at 2.53 and 2.54, respectively, indicating that sample teachers feel fairly equally prepared in each of these two domains.

In order to determine if the differences in the means were significant, I conducted a repeated measures ANOVA on the four types of teacher knowledge. Mauchly's test indicated that the assumption of sphericity had been violated (chi-squared=14.19, $p<.05$), therefore degrees of freedom were corrected using Huynh-Feldt estimates of sphericity (epsilon=.91). The results show that the mean scores for the domains differed significantly, $F(2.81, 270.06)=24.03$, $p<.001$ (Table 8). Post hoc pair wise comparisons revealed that although mean MK is significantly higher than both mean PCK and mean PK ($p<.05$ and $p<.001$, respectively), it was not significantly higher than mean CK. Additionally, mean PCK was not significantly different than mean CK (see Table 9) although it was significantly higher than mean PK ($p<.05$).

Table 8

Within-Subject Effects for Four Knowledge Domains

| Source | | *df* | Mean Square | *F* | *p* |
|---|---|---|---|---|---|
| Four Knowledges | Sphericity Assumed | 3.00 | 5.75 | 24.03 | .000 |
| | Greenhouse-Geisser | 2.73 | 6.33 | 24.03 | .000 |
| | Huynh-Feldt | 2.81 | 6.14 | 24.03 | .000 |
| | Lower-bound | 1.00 | 17.26 | 24.03 | .000 |
| Error (Four Knowledges) | Sphericity Assumed | 288.00 | .25 | | |
| | Greenhouse-Geisser | 261.67 | .26 | | |
| | Huynh-Feldt | 270.06 | .26 | | |
| | Lower-bound | 96.00 | .72 | | |

Table 9

Pair Wise Comparisons of Mean Differences Between Four Knowledge Domains

| Knowledge 1 | Knowledge 2 | Mean Difference | *SD* | *p* |
|---|---|---|---|---|
| MK | PCK | .13 | .06 | .040 |
| | PK | .56 | .07 | .000 |
| | CK | .12 | .08 | .151 |
| PCK | MK | -.13 | .06 | .040 |
| | PK | .43 | .06 | .000 |
| | CK | -.01 | .07 | .882 |
| PK | MK | -.56 | .07 | .000 |
| | PCK | -.43 | .06 | .000 |
| | CK | -.44 | .07 | .000 |
| CK | MK | -.12 | .08 | .151 |
| | PCK | .01 | .07 | .882 |
| | PK | .44 | .07 | .000 |

These results reveal how novice teachers perceive their relative preparedness in each of the domains. Hence, these data allow us to begin to understand the order of teachers' perceived level of preparedness. They view that they are more prepared in MK than they are in PCK (mean difference of .13, $p$=.040) and even more so than they feel prepared in PK (mean difference of .56, $p$=.000). Additionally, they perceive that their preparedness in CK is about the same as it is for MK ($p$=.151). Though novice teachers feel more prepared in MK than in PCK, they feel about the same level of preparedness in PCK as they do in CK ($p$=.882). It is clear, though, that they feel the least prepared in PK. Their level of preparedness in PK is significantly lower than MK (mean difference of -.56, $p$=.000), CK (mean difference of -.44, $p$=.000), and PCK (mean difference of .43, $p$=.000), respectively.

Next, I investigated the correlations between each of the domains to determine the association between each. Results show that the domains are positively correlated to one another with correlations in the moderate range (see Table 10). Mathematical Knowledge is most strongly correlated to PCK, $r$=.62, $p$<.01 (2-tailed) and least with CK, $r$=.44, $p$<.01 (2-tailed). Pedagogical Content Knowledge is more closely correlated to both PK, $r$=.57 $p$<.01 (2-tailed) and CK, $r$=.60 $p$<.01 (2-tailed) than MK to those domains. Thus, MK, the knowledge in which novice teachers report feeling most prepared, is the knowledge most strongly correlated to one other knowledge, PCK—explaining 38% of the variance in PCK. PCK, the knowledge in which novice teachers report feeling "second most" prepared (along with CK), has a stronger correlation to the two other knowledges, PK and CK—explaining 32% and 36% of the variance in

Table 10

Correlations of Domains of Mathematics Teacher Knowledge Domains

| | Mathematical Knowledge | Pedagogical Content Knowledge | Pedagogical Knowledge | Curricular Knowledge |
|---|---|---|---|---|
| Mathematical Knowledge | 1.0 | 0.62** | 0.46** | 0.44** |
| Pedagogical Content Knowledge | | 1.0 | 0.57** | 0.60** |
| Pedagogical Knowledge | | | 1.0 | 0.54** |
| Curricular Knowledge | | | | 1.0 |

**$p$<0.01

each, respectively. Additionally, while means for MK and CK do not statistically differ, these two knowledges have the lower correlation ($r$=44, $p$<.01).

Since teachers report that they felt most prepared in the domain of MK, and MK was most strongly correlated to PCK, which in turn was most strongly correlated to PK and CK, I further investigated whether or not there was a difference in the means of teachers' self-reported knowledge in each of the domains with different levels of mathematics teaching endorsement as the independent variable. In Utah, there are three levels of secondary mathematics endorsements: level 2, level 3 and level 4. A level 2 mathematics teaching endorsement is generally for teachers in grades 1-8 extending their mathematics study, a level 3 mathematics teaching endorsement is equivalent to a college minor in mathematics, and a level 4 mathematics teaching endorsement is equivalent to a college major in mathematics (see Appendix B for mathematical courses for each level of endorsement). Of the respondents that reported level of mathematics endorsement, 8 had a level 2 mathematics endorsement, 13 had a level 3 endorsement, 63 had a level 4 endorsement, 2 did not know their level of endorsement, and 8 had not yet received a math endorsement. The differences in the sizes of each of these groups are a problem because it violates one of the assumptions of a one-way ANOVA. However, the Test for Homogeneity of Variances indicated that the variances were not significantly different, so I conducted the one-way ANOVA. The results led me to conclude that there is no difference in the means of teacher knowledges when level of mathematical endorsement is the independent variable (see Table 11). For MK, no differences between means were found for the different levels of mathematics endorsement, $F(4,89)=.718$, $p>.05$. This

Table 11

One-way ANOVA Comparison of Means of Secondary Teaching Knowledge with Mathematics Level of Endorsement as Independent Variable

| | | Sum of Squares | *df* | Mean Square | *F* | *p* |
|---|---|---|---|---|---|---|
| MK | Between Groups | 1.56 | 4 | .39 | .718 | .582 |
| | Within Groups | 48.18 | 89 | .54 | | |
| | Total | 49.74 | 93 | | | |
| PCK | Between Groups | .763 | 4 | .19 | .417 | .796 |
| | Within Groups | 40.71 | 89 | .46 | | |
| | Total | 41.48 | 93 | | | |
| PK | Between Groups | .13 | 4 | .03 | .091 | .985 |
| | Within Groups | 31.54 | 89 | .35 | | |
| | Total | 31.48 | 93 | | | |
| CK | Between Groups | .51 | 4 | .13 | .189 | .943 |
| | Within Groups | 60.24 | 89 | .68 | | |
| | Total | 60.76 | 93 | | | |

was also the case for PCK, $F(4,89)=.417, p>.05$, PK, $F(4,89)=.091, p>.05$, and CK, $F(4,89)=.189, p>.05$. Post hoc comparisons also did not show differences in the means.

Research Question 3

*Where do novice mathematics teachers report they gained their knowledge and skills for teaching?* In order to determine where teachers gained their knowledge for each of the four domains, responses from Question B in Part I of the survey were collapsed into three categories: "in college," "student teaching," and "outside of college." Respondents were give seven response choices: (a) in my college math classes, (b) in my college education or licensure classes, (c) in my college math methods or pedagogy classes, (d) during my student teaching experience, (e) from my own personal experiences (e.g., as a student or tutor), (f) during my initial teaching experience, and (g) I am working on learning this skill. Choices a, b, and c were collapsed into "in college," choice d was labeled "student teaching," choices e and f were collapsed into "outside of college," and g was labeled "other." I then combined each of the four domain responses by the collapsed variable and found the mean score for each (i.e., Mathematical Knowledge in college, Mathematical Knowledge student teaching, Mathematical Knowledge outside of college, etc.), which represented the percent of knowledge gained in each of the three settings for each type of knowledge (i.e., Mathematical Knowledge in college was .5412; hence, respondents reported that they gained 54.12% of their Mathematical Knowledge in college). Finally, I analyzed the differences in the mean percents by conducting paired *t*-tests on the mean percentages for each of the knowledges for in and out of college.

### Descriptive Statistics of Where Novice Teachers Report They Gained Their Knowledge

Teachers report that they gained most of their MK (54%) in college, but that they gained most of their other knowledge outside of college. They report that they gained 34% of their PCK, 42% of their PK, and 29% of their CK in college while they report that they gained 59% of their PCK, 51% of their PK, and 63% of their CK outside of college (see Table 12). Teachers report that for all four domains, they gained the least amount of their knowledge during student teaching. For all four domains, the amount of their knowledge gained during student teaching was less than 10% (mathematical knowledge 2%, pedagogical content knowledge 7%, pedagogical knowledge 7%, and curricular knowledge 8%).

Table 12

Where Secondary Mathematics Teachers Gained Their Knowledge in Each of the Domains

| | | *N* | Min. | Max. | Mean | *SD* |
|---|---|---|---|---|---|---|
| Mathematical Knowledge | In college | 95 | .00 | 1.00 | .54 | .32 |
| | Student teaching | 95 | .00 | .27 | .02 | .06 |
| | Outside of college | 95 | .00 | 1.00 | .44 | .32 |
| Pedagogical Content Knowledge | In college | 96 | .00 | 1.00 | .34 | .35 |
| | Student teaching | 96 | .00 | .75 | .07 | .17 |
| | Outside of college | 96 | .00 | 1.00 | .59 | .36 |
| Pedagogical Knowledge | In college | 96 | .00 | 1.00 | .42 | .39 |
| | Student teaching | 96 | .00 | 1.00 | .07 | .19 |
| | Outside of college | 96 | .00 | 1.00 | .51 | .38 |
| Curricular Knowledge | In college | 95 | .00 | 1.00 | .29 | .37 |
| | Student teaching | 95 | .00 | 1.00 | .08 | .20 |
| | Outside of college | 95 | .00 | 1.00 | .63 | .39 |

I then conducted two-tailed paired *t*-tests to see if there was a statistical difference in the mean percents for in and out of college. I did not include student teaching because for all four domains, teachers reported that they gained less than 10% of their knowledge during student teaching. Results indicate that although teachers report gaining the majority of their MK in college, a statistical difference between the means of in college and outside of college was not found ($p$=.106). Additionally, there is not a statistical difference in their reporting gaining PK outside of college rather than in college ($p$=.262). There is statistical significance, however, in the difference of the means of PCK and CK for in college rather than outside of college, $t(95)$=-3.503 and $t(94)$=-4.455 respectively, $p$<.01 (see Table 13). As mentioned above, each of the t-tests were conduced as a two-tailed test ($H_o$ = there is no difference in the means between in college and outside of

Table 13

Paired Sample *t*-test Comparison of Mean Percents of Perceived Knowledge Gained In College and Outside of College for Each of the Four Domains of Knowledge

| Pairs | Mean Difference | *t* | *df* | *p* (2-tailed) |
|---|---|---|---|---|
| Mathematical Knowledge<br>In College & Outside of College | .11 | 1.63 | 94 | .106 |
| Pedagogical Content Knowledge<br>In College & Outside of College | -.25 | -3.50 | 95 | .001 |
| Pedagogical Knowledge<br>In College & Outside of College | -.09 | -1.13 | 95 | .262 |
| Curricular Knowledge<br>In College & Outside of College | -.33 | -4.46 | 94 | .000 |

college). Two alternative hypotheses that MK in college is greater than MK outside of college, and PK outside of college is greater than PK in college, were tested with one-tailed t-tests that indicated no significant difference between the means, with p=.053 and p=.131, respectively. Thus, data indicate that respondents perceive they gained most of their skills and knowledge in the domains of PCK and CK for teaching secondary mathematics outside of college, but that for the domains of MK and PK, respondents are getting their knowledge both in college and outside of college.

## Research Question 4

*Do novice mathematics teachers prepared in Utah institutions report any differences in their knowledge and skills for teaching secondary mathematics?* To determine if teachers from the different institutions in Utah report differences in their mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, or curricular knowledge, I conducted a frequency distribution of where novice teachers reported they earned their secondary licensure. Respondents identified nine institutions in Utah, with four representing 61% of the responses: Brigham Young University 24.2%, Southern Utah University 10.5%, University of Utah 12.6%, and Utah State University 13.7% (see Table 1 for all institutions identified). A new variable was created that identified only these four institutions and then a one-way ANOVA was conducted with each of the four domains of knowledge as the dependent variable and institution as the factor. No discernable differences were found in any of the four knowledge domains of novice teachers for the four institutions: for MK $F(3,54)=1.53$, $p>.05$, for PCK $F(3,54)=1.47$ $p>.05$, for PK $F(3,54)=.449$ $p>.05$, and for CK $F(3,54)=1.09$ $p>.05$ (see Table 14).

Table 14

One-way ANOVA for Institution Factor and Domains of Secondary Teacher Knowledge

| | | Sum of Squares | *df* | Mean Squared | *F* | *p* |
|---|---|---|---|---|---|---|
| MK | Between Groups | 1.87 | 3 | .62 | 1.531 | .217 |
| | Within Groups | 21.95 | 54 | .41 | | |
| | Total | 23.82 | 57 | | | |
| PCK | Between Groups | 1.36 | 3 | .45 | 1.470 | .233 |
| | Within Groups | 16.62 | 54 | .31 | | |
| | Total | 17.98 | 57 | | | |
| PK | Between Groups | .40 | 3 | .13 | .449 | .719 |
| | Within Groups | 15.99 | 54 | .30 | | |
| | Total | 16.39 | 57 | | | |
| CK | Between Groups | 1.82 | 3 | .61 | 1.091 | .361 |
| | Within Groups | 30.04 | 54 | .56 | | |
| | Total | 31.86 | 57 | | | |

Conclusion

In summary, the data show there are four domains of knowledge for novice teachers: mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge. Teachers feel most prepared in the domain of mathematical knowledge and least in the domain of pedagogical knowledge. They feel similarly prepared in the domains of pedagogical content knowledge and curricular knowledge. Further, the data indicate that there is significance in the differences in the means of all the domains except for the differences between the means of mathematical knowledge and curricular knowledge and for pedagogical content knowledge and curricular knowledge. Differences in means persist even when the data are disaggregated for different levels of mathematics endorsement, though this finding is problematic due to the differences in the sizes of the groups. Further, data indicate that teachers report they gain their mathematical and pedagogical knowledge both in and out of college, but that they gain their pedagogical content and curricular knowledge primarily outside of college. There appears to be no discernable difference for novice teacher self-reported knowledge in the four domains for the four Utah institutions evaluated. A discussion of the relevance of these findings for policy follows in the next chapter.

CHAPTER 5

RETHINKING SECONDARY MATHEMATICS

TEACHER PREPARATION

Purpose of the Study

The purpose of this study was to examine secondary mathematics teacher preparation from the perspective of the novice teacher. The overriding goal was to ascertain the extent to which novice teachers feel prepared to do the work of teaching as they enter the profession. This information would then address how to improve teacher preparation in secondary mathematics specifically, mathematics teacher quality, and student achievement in mathematics in general.

This research is based on the perspective that quality teaching is primarily a function of quality preparation and continual training, not of sanctions or rewards and other incentives (Ball, 2009). Ensuring that every secondary student has a quality mathematics teacher begins by ensuring that all secondary mathematics teachers develop the skills and knowledge they need to do the work of teaching *before* they enter the classroom.

Framework

This dissertation offers a framework for the work of novice secondary mathematics teachers. The framework is built on the work of Ball, Thames, and Phelps

(2008), Hill, Ball, and Schilling (2008), Shulman (1986), and others. It suggests that content (mathematical) knowledge and pedagogical knowledge, the two domains around which teacher preparation typically focuses, do not fully address the knowledge and skills novice mathematics teachers need as they begin the work of teaching. I suggested two additional domains as essential in teacher preparation, pedagogical content knowledge, and curricular knowledge, and suggested these needed explicit attention during preparation.

The framework offered herein suggests that the four domains are interrelated, but separate. Although teachers develop knowledge and skills in each of the domains in conjunction with the knowledge and skills in other domains, each of the domains must be uniquely and explicitly addressed during preparation. Further, I suggested that without teacher preparation addressing the domains explicitly, teachers would not develop needed knowledge and skills of teaching mathematics before entering the classroom.
Lastly, the definitions of the domains in the framework offer a conceptualization of how the knowledge and skills of *teaching* secondary mathematics is different then the knowledge and skills of *knowing* or *doing* secondary mathematics. Thus, the framework offers teacher preparation policy and research a perspective on which types of knowledge and skills explicitly must be developed during teacher preparation.

## Limitations

There are several limitations on this study. First, this study only assesses the perspective of novice teachers working in Utah. Hence, generalizability is limited. Further assessment of novice teachers around the country is necessary.

Another limitation is the survey instrument used for this research. Since the framework is new, the instrument used to assess the framework is new. The instrument needs further examination and refinement. Many of the items in the survey relating to each of the domains need to be rewritten and refined. Additionally, more items need to be developed for pedagogical knowledge, pedagogical content knowledge, and particularly for curricular knowledge. Items on the survey that did not load on one of the factors representing the four domains of teacher knowledge also need to be carefully assessed to determine if either further exploration of the factors needs to be done, or if the items were simply poor items. Also, the instrument was too long and therefore may have discouraged teachers from participating.

Additionally, data for this research relied on teachers' self-reported perceptions of preparedness. Though it was my explicit intent to examine teacher preparation from the perspective of the novice teacher, self-reported data can be problematic, particularly in terms of ascertaining where teachers believe they gained their skills and knowledge.

A final limitation of this research is the low response rate for the survey. The USOE query identified 562 novice mathematics teachers for the 2008-2009 academic year, and of those 562 novice teachers, this research is based on 95 responses. Hence, the response rate for the survey was 16.9%. The relatively low response rate calls into question the generalizability of the findings. Further research will seek to increase the response rate and will also seek a sample that extends beyond Utah in order to overcome these limits to generalizability.

Research Questions

*Do novice secondary mathematics teachers' perceptions of their knowledge and skills in the work of teaching fall into the four proposed conceptualized domains—mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge?* The exploratory factor analysis of Question A in Part 1 of the survey indicates that novice teachers' perspectives of their knowledge and skills do indeed fall into the four domains conceptualized by the framework: mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge. The data indicate that these domains are correlated with one another, but independent. Hence, the domains are appropriate for examining teachers' sense of preparedness to do the work of teaching and suggest a framework for thinking about secondary mathematics teacher preparation.

The separation of the domains supports and extends the research upon which the conceptual framework was built. Content and pedagogical knowledge have long been central to defining core content as included in teacher preparation, however, researchers such as Shulman (1986) have noted that it is not completely clear what content and pedagogical knowledge is most important for individuals as they enter the profession. This research provides empirical evidence that there are four domains of knowledge and skills of novice teachers. The domain of mathematical knowledge supports the work of Ball, Thames, and Phelps (2008). Its uniqueness from pedagogical content knowledge extends the work of Hill (2008) and Hill, Rowan, and Ball (2005) as well as Shulman (1986). The separation of pedagogical content knowledge from the domain of pedagogical knowledge grew from the work of Cochran-Smith and Fries (2005) and from

Fennema and Franke (1992). The distinctness of curricular knowledge extends the work of Shulman (1987) and Hill, Ball, and Schilling (2008).

Of particular importance among the findings of this research is the fact that pedagogical content knowledge and curricular knowledge, typically not explicitly defined as domains in teacher preparation, are distinct both from each other and from mathematical knowledge and pedagogical knowledge. This supports the claim proposed in the conceptual framework that the domains of content (mathematical) knowledge and pedagogical knowledge are not sufficient in accounting for the types of knowledge and skills novice teachers need in doing the work of teaching secondary mathematics. This finding points to the need for teacher education to address explicitly these domains as a framework for teacher preparation in secondary mathematics.

This research question was supported by the following hypothesis: *Novice teachers perceive that their work falls into four separate domains—mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge*. The analysis confirms hypothesis 1. The factor analysis conducted on part I of survey responses indicates that the four proposed domains are separate and distinct. The confirmation of this hypothesis may lead to more constructive ways to think about teacher preparation and licensure.

*To what extent do novice teachers perceive they are prepared to do the work of teaching secondary mathematics?* Analysis of mean scores of novice mathematics teachers' sense of preparedness in each of the domains revealed that they feel most prepared in the domain of mathematical knowledge ($\bar{X}$=2.66 out of 4) and least prepared in pedagogical knowledge ($\bar{X}$=2.10 out of 4). Their sense of preparedness in the domains of pedagogical content knowledge ( $\bar{X}$=2.53 out of 4) and curricular knowledge ( $\bar{X}$=2.54 out of 4) falls between mathematical knowledge and pedagogical knowledge and is not significantly different from each other.

Using each of the lenses offered by Cochran-Smith and Fries (2005) provides unique perspectives of the results of this research. They noted that teacher preparation has been defined as a training problem, as a learning problem, and as a policy problem. As a training problem, research in teacher education focused on "transportable training procedures that had an impact on teacher behaviors" (Cochran-Smith & Fries, 2005, p. 77). As a learning problem, research evolved into "understanding teachers' knowledge development; sources and use of knowledge, beliefs, and attitudes; the teacher education pedagogies that promote knowledge development; and how people learn to teach over time" (Cochran-Smith & Fries, 2005, p. 84). From the first perspective, teacher preparation as a training problem, we can argue that teacher preparation is not explicitly "training" in all four of the domains. From the second perspective, teacher preparation as a learning problem, we can argue that teachers are not "learning" the knowledge and skills they need in the current structure to do the work of teaching when they enter the classroom. And from the third perspective, teacher preparation as a policy problem, we can argue that policy must be addressed to rectify deficits implied by the findings.

Teachers in the sample feel most and least prepared in the domains of mathematical and pedagogical knowledge, respectively. Given that teacher preparation is organized around these domains, it would seem natural that these two domains should be where teachers feel the most prepared. Yet, though teachers report feeling most prepared in the domain of mathematical knowledge, they report feeling least prepared in the domain of pedagogical knowledge. If we look at this framed as a training problem or a learning problem, we can conclude that for mathematical knowledge, there is neither a training nor a learning problem. However, for pedagogical knowledge, there must be a training problem because individuals entering teaching are receiving training in pedagogy, but they are reporting not being well prepared. In other words, the training they are getting is not "transferring" to them, or is not impacting their behaviors.

In the conceptual framework, I defined pedagogical knowledge by building on the works of Cochran-Smith and Fries (2005) and Fennema and Franke (1992) as the knowledge and skills associated with non-content-specific aspects of teaching and learning such as the knowledge and skills needed for teaching English language learners and students requiring special education services. Coursework requirements for licensure in Utah include training for both teaching students who are English language learners and students with disabilities. Hence, teachers are receiving preparation in this domain, yet they are reporting feeling the least prepared in it. Understanding what elements of current coursework in this domain are beneficial and not beneficial is essential in beginning the process of ensuring that teachers are receiving the training they need for this domain. There also needs to be better evaluation as to whether or not teachers have learned the skills essential in this domain.

The conceptualization of pedagogical knowledge precisely identifies skills and knowledge around specific aspects of teaching students with diverse needs. One possible way to assess applicability of current coursework to this domain is to evaluate if courses should focus on *how* or *why* students have diverse learning needs or if they should focus on *strategies* for addressing those diversities. The difference is subtle, but may be at the core of the issue with pedagogy classes.

Mathematical knowledge is the domain in which novice teachers feel the most prepared. This is not surprising given the extent of coursework most secondary teachers have in mathematics: that is anywhere from 21 semester hours to upwards of 45 semester hours in Utah, depending on the level of endorsement. Yet teachers in the sample reported that on a 4-point Likert-type scale, their perceived level of preparedness in mathematical knowledge was only 2.66. Sixty-three of the survey respondents had a level 4 mathematics endorsement; thus, they completed coursework similar to that of a major in mathematics (see Appendix B). However, the one-way ANOVA did not show a statistical difference between perceived preparedness in mathematical knowledge for different levels of endorsements. Hence, teachers with more (traditional) mathematical training, defined by coursework, did not report that they feel more prepared in mathematics than teachers with less (traditional) training in mathematics. This evidence suggests that the mathematical training teachers are getting in college may not be the training teachers need to do their work. In other words, this is evidence of a training problem.

Completing coursework equivalent to a bachelor's degree in mathematics is the norm throughout the country for secondary mathematics licensure. The mathematics courses pre-service teachers take are not designed only for individuals interested in degrees in mathematics or mathematics education. These courses also prepare those interested in becoming engineers, doctors, scientists, etc. Preparing all disciplines with the same mathematics courses implies that there is no difference in how all these professions and individuals must understand and be able to do mathematics. The research of Ma (1999), Ball (1990), and Ball, Thames, and Phelps (2008), for example, has begun to challenge the assumption that these mathematical courses designed to serve all students are sufficient for preservice mathematics teachers by showing that teachers need to understand mathematics in a different way than other professionals who use mathematics. A classic example of how teachers need to understand mathematics differently than other professions is that teachers must have the ability to explain *why*, for example, the "invert and multiply" algorithm works for division of fractions. Other professionals must simply be able to *do* the division of fractions algorithm. Teachers must be able to *do* it and *explain* it in a way a child can understand. If teachers are receiving the same coursework in mathematics as other professionals, but need to understand mathematics in a different way, they should receive different training in the content.

As for both pedagogical content knowledge and curricular knowledge, preparation does arguably contain some training in these domains. However, the data from this research indicates that it is neither sufficient nor is it explicit enough. Applying the notion of whether there is a training or a learning problem for these domains, it is clear that there is both.

This research question was supported by the following hypothesis: *Novice teachers vary in the degree to which they feel prepared in each of the four conceptualized domains.* The results of the analysis confirm this hypothesis. Teachers perceive that they are most prepared in the domain of mathematical knowledge, while they report that they are least prepared in the domain of pedagogical knowledge. Teachers' perceived level of preparedness in the domains of pedagogical content knowledge and curricular knowledge falls between there perceived level of preparedness in mathematical knowledge and pedagogical knowledge.

*Where do novice mathematics teachers report they gained their knowledge and skills for teaching?* Implications of the first two research questions make this research question even more essential to understanding secondary mathematics teacher preparation from the perspective of novice teachers. For mathematical and pedagogical knowledge, teachers in the sample indicated that they gained their knowledge both in college and while they were teaching (outside of college), whereas for pedagogical content and curricular knowledge, teachers in the sample reported that they gained those skills primarily while they were teaching (outside of college). It is not surprising that novice teachers reported that they gained at least a portion of their mathematical and pedagogical knowledge in college (prior to teaching) given that both preparation and licensure focus on these domains. What is noteworthy, however, is that there is not clear evidence that teachers feel that they gained *most* of their knowledge in college (prior to entering teaching) for these domains. The analysis indicates that there is no domain wherein secondary mathematics teachers feel they primarily gained their knowledge and skills *before* they began teaching. Consequently, for all domains, teachers reported that they gained much of their knowledge and skills for teaching mathematics while working with students. These data indicate that the transition from expert student to novice teacher may be happening later than we expected--while teachers are actually working with their own students and not under the supervision of either a teacher preparation program or a cooperating teacher.

The premise of this dissertation is that teacher preparation matters (Darling-Hammond & Youngs, 2002) and that the goal of teacher preparation is to ensure that new teachers entering the classroom are prepared to do the work that we ask of them (Ball, 2009). Teachers in this sample, however, seemed to indicate that they were not prepared ahead of time to do the work that we ask of them in a secondary mathematics classroom given that they are saying they gained about half of their mathematical knowledge and pedagogical knowledge outside of college as well as most of their pedagogical knowledge and curricular knowledge.

The implications of this finding relate back again to the notion of a problem in teacher preparation of training versus learning. The analysis indicates that the problem is both one of training and of learning. Training needs to both be more focused on the knowledge and skills associated with the work that teachers are doing and a need to better understand how prospective teachers are learning the knowledge and skills they need from their training.

This research question was supported by the following hypothesis: *Novice teachers will report that they gained mathematical knowledge in college, but that they gained pedagogical, pedagogical content, and curricular knowledge outside of college.* The analysis only partially supports this hypothesis, however. The analysis indicates that teachers perceived that they gained their mathematical and pedagogical knowledge both in college and outside of college, but that they gained most of their pedagogical content and curricular knowledge outside of college.

*Do novice mathematics teachers who were prepared at different institutions report any differences in their knowledge and skills?* Novice teachers in the sample did not report differences in their perceptions of their preparedness in any of the domains by institution in which they were prepared. This indicates a general and consistent structure and nature of secondary mathematics preparation across the four Utah institutions in the analysis. This finding seems to contradict research by Goodlad (1990) indicating that teacher preparation programs vary significantly in nature and quality. For this sample, it appears that the similar nature and structure of teacher preparation, rather than the individual institution, lead teachers to feel similarly prepared in all the domains. In other words, the analysis points to a problem in the required coursework for licensure, rather than a problem with institutions' implementation of the required coursework. The implication is that there must be a rethinking of coursework requirements for licensure in Utah.

This research question was supported by the following hypothesis: *There are not discernable differences between teacher preparation institutions in terms of perceptions of novice teachers' beliefs in their preparedness.* As with the first two hypotheses, data from the research support this hypothesis. Teachers' reported perceptions in preparedness in all domains did not vary by institution.

## Policy Implications

The central purpose of this study is to examine teacher preparation as a means of improving teacher quality to ultimately improve student achievement in mathematics. This study emerged from the perspective that the role of education policy around teacher preparation is to ensure that only those well prepared to do the work of teaching enter the classroom in the first place. To meet these objectives, I constructed a conceptual framework of knowledge and skills needed for teachers as they begin to do the work of teaching and then I examined whether or not the framework indeed accurately represented how novice teachers perceive their work. Next, I examined the degree to which novice teachers felt prepared in each of the conceptualized domains and where they felt they gained their skills. Finally, I investigated if differences in teachers' sense of preparedness could be attributed to the different Utah institutions in which they received their training.

The empirical findings are consistent with the conceptual framework that articulates four distinct domains of teacher knowledge and suggest that teachers do not feel as prepared in any of the domains as one might hope. Further, respondents reported that they gained a considerable amount of their knowledge and skills for teaching while teaching rather than before they began the work of teaching. Finally, perceptions of preparedness do not vary by the Utah institutions examined. The implications of these finds suggest a radical rethinking of teacher preparation and licensure.

The recommendations I make build on the findings of this study as well as the vision for mathematics teacher preparation offered Howey (1996), the ideas of Ball et. al (2008) and Hill et. al (2007) regarding mathematical knowledge for teaching, and Cochran-Smith et. al (2003) who argue that teacher education should not add on to the current structure of teacher preparation; rather, it should fundamentally reinvent structures and emphasize resources rather than deficit perspectives of diversity.

There are two broad categories for recommendation. The first category of recommendations is for teacher preparation in secondary mathematics and the second category of recommendations is for licensure. These recommendation emerge from the same perspective that has guided this study: a) teacher preparation matters and b) the importance of the role of policy in teacher preparation is to ensure that only those well prepared to do the work of teaching enter the classroom to teach.

It is also important to point out that data from this research indicate that the knowledge and skills needed by novice teachers to do their work are learnable. The issue is that it appears that teachers are gaining much of their knowledge and skills while doing the work of teaching, rather than gaining them before entering the classroom. Hence, the recommendations also emanate from the perspective that the structure and content of preparation and licensure can and should ensure that individuals enter the classroom ready to do the work of teaching.

## Recommendations for Preparation

Recommendations offered herein for preparation in secondary mathematics will focus on both the structure and content of preparation. By "structure" I mean how coursework is outlined, the amount and type of coursework required of individuals preparing to do the work of teaching, and alternative perspectives to traditional coursework for preparation. By "content" I mean the topics within coursework or field experiences of preservice teachers. All recommendation made herein will focus only on preparation for preservice teachers. More explicitly, I will not make recommendations for how to transition individuals into the work of teaching after they have completed coursework for preparation.

### Structure of Preparation for Teaching Secondary Mathematics

The current structure of teacher preparation in secondary mathematics varies across the country but in general requires individuals to complete coursework equivalent to a college major in mathematics with additional classes in pedagogy. Content pedagogy coursework usually falls within the coursework of mathematics and are therefore offered through the college of mathematics within institutions. Within those courses (usually one or two), mathematics curriculum is also examined. Coursework in pedagogy is delivered by the college of education and generally includes a variety of coursework that is non-content-specific aspects of teaching such as courses in management, literacy across all contents, history and theory of education, and how to work with students of diverse backgrounds (cultural or learning.) Field experiences are included at various levels throughout preparation and culminate with an extended "student teaching" period at the end of coursework.

Decisions regarding the structure of coursework for preparation are driven by licensure requirement, which are made outside of the institutions preparing individuals to become teachers. However, institutions have significant latitude in determining how coursework is delivered, goals of the coursework, who delivers the coursework, and what is contained in the coursework. (Licensure requirements will be discussed in the next section.)

Structures for delivering coursework to individuals preparing to become secondary teachers of mathematics within institutions of preparation need to a) be restructured to focus on the four domains identified by the research herein; b) be cooperatively redesigned and delivered between the colleges of education and mathematics within institutions; and c) be more deliberate in facilitating the transition between theory and practice by restructuring field experiences.

Restructure Focus of Coursework around the Four Domains

Currently, coursework within institutions is structured around the domains of content and pedagogy, proportionate to both licensing structures and the college within which the courses are offered. Within content courses there are courses specifically designed for pre-service teachers. For example, in Utah, there are three courses delivered by the college of mathematics most specifically for individuals seeking to become teachers: Foundations of Algebra (or Algebraic Structures), Euclidian and Non-Euclidian Geometry, and Methods of Teaching Secondary Mathematics. These courses in general seek to develop preservice teachers' skills in both the content of mathematics and how to teach that content; thus, they are arguably pedagogical content knowledge courses. Additionally, it is within these courses that the curriculum of secondary mathematics is addressed, so it could also be argued that one or all these courses also address curricular knowledge courses. However, these courses are not categorized as either PCK or CK courses; they simply are "required" mathematics courses for secondary teachers of mathematics.

One of the implications of the findings within this study is that by not explicitly structuring coursework around the goal of developing pedagogical content knowledge or curricular knowledge, teachers are learning these skills while they are working with students. In other words, because the goals of these classes are not for the purpose of preparing individuals in specific domains (PCK or CK), results are inconsistent and unsatisfactory in those domains.

This is arguably the issue also with pedagogical knowledge coursework. Courses in this domain are typically conducted within the college of educations and are, as

Cochran-Smith and Fries (2005) pointed out, rendering poor results as well. Here, though, the issue is even more urgent in that (a) student population is rapidly becoming more diverse; (b) the achievement gap between students who are White and those of various ethnic backgrounds, particularly at the secondary level in mathematics, is extremely concerning; and (c) it appears that teachers are having difficulty learning the skills and knowledge they need for this domain even after they commence teaching. Building on the work of Cochran-Smith and Fries (2005), the structure of coursework in this domain must be radically altered. Here, coursework must go beyond pointing out the differences in backgrounds of different groups of students to moving to bridging varied cultures and learning challenges to reaching content. With these goals, institutions must continually assess the success of their structures in meeting the goals of the domains.

### Cooperatively Redesign and Deliver Coursework for the Domains Between the Colleges of Education and Mathematics within Institutions

Though it is generally agreed that developing both content and pedagogy are essential in teacher preparation, cooperation between colleges of education and mathematics to work in harmony for these goals is often not the norm. The result is that for the topics on which content and pedagogy overlap, preparation is weak as is evidenced by the findings within this study. For the domains such as pedagogical content knowledge and curricular knowledge, cooperation between colleges is essential. What stands in the way of complete cooperation is the fact that courses fall under one or the other college. This is particularly concerning for PKC and CK courses where content and pedagogy blend so completely. Institutions must find a way to merge interests of individual colleges with the needs of preparing individuals for doing the work of teaching mathematics. This may mean creating colleges of mathematics education or structuring certain classes to be both education and mathematics courses. This of course, calls for a radical rethink of the structure of courses in both colleges.

Deliberately Facilitating the Transition between Theory
and Practice by Restructuring Field Experiences

The findings of this research clearly show that teachers are gaining a great deal of knowledge and skill while working with students. Though this is problematic from the perspective that novice teachers are not entering the classroom with the knowledge and skills they need to do the work of teaching, it is evidence that learning does occur for individuals while working with students. The implication is that teacher preparation should better use field experience to prepare individuals to do the work of teaching.

Preservice teachers are required to observe instruction and sometimes do “mini-lessons” as part of their preparation. Additionally, they often do a “field practicum.” At the end of preparation, preservice teachers have a “student teaching” experience. This experience is designed to transition individuals from the world of the “theory” of teaching to the “practice” of teaching by giving preservice teachers an opportunity to do lesson plans, implement instruction, manage a classroom, and interact with students, parents, and other education personnel. This structure needs to be carefully re-examined and then restructured to better prepare individuals before they are responsible for their own students. I make three recommendations. First, supervision of student teaching needs to be a cooperative between the colleges of mathematics and colleges of education. Second, the student teaching experience should be more of an apprentice model rather than a practice-teaching model. And third, student teaching should be structured as an extended portion of preparation for teaching.

A person from within the college of education generally fills the role of supervising instructor for student teaching in that the student teaching course falls within that college. It is essential that the supervising instructor not only be familiar with non-content specific aspects of teaching: she or he must also be very familiar with the content, content pedagogy, and the curriculum of the subject being supervised. Hence, this again requires cooperation between the colleges of education and mathematics to ensure that preservice teachers are best prepared.

Student teaching, like most other aspects of teacher preparation, varies significantly across institutions and even within institutions, so generalizations about what student teaching looks like is not only difficult, it is impractical. Therein, however, lies the problem. The structure for student teaching is neither consistent nor standardized. Data from this research indicate that there are no discernable differences in teachers' perceptions of preparedness by four Utah institutions. So it appears that, at least for the four institutions examined, all need to reevaluate their structure for not only preparation in general, but for student teaching specifically.

A rethinking of student teaching should include a better utilization of the experienced master teacher with whom the preservice teachers works and an acknowledgement of the importance of that role for the progression of an individual from expert student to novice teacher. I am suggesting that rather than thinking of that individual as the "cooperating teacher" the paradigm should change to view that individual as the master or mentor teacher for the preservice teacher. His or her role should be that of modeling good teaching, pre- and postmetacognitive discussion of the work of teaching, team teaching with the student teacher, and guiding the student teacher before, during, and after she or he teaches. I am suggesting a role that is far more extensive than is generally thought of as the role of "cooperating teacher." Further, I am suggesting that this role be connected to both the colleges of mathematics and education in a spirit of cooperation and acknowledgement of the interdependence of the knowledge and skills within both colleges required in the work of teaching mathematics. Lastly, I am suggesting that this role is so vital and demanding that the individual fulfilling it be compensated in a manner that reflects its importance of insuring preparation of future teachers and the demand of time it requires.

Finally, in terms of rethinking the transition of theory to practice, I am suggesting that student teaching be an ongoing integral component of preparation. Currently, formal student teaching is one semester and is done after coursework is completed. Preservice teachers often do observations as part of their coursework in both the college of mathematics and education; but again, the effort is not uniformly structured. The role of the observed teacher is also not uniformly structured. If student teaching were a prolonged structure, three to four semesters, in which the preservice teachers were paired with a master teacher with whom she or he could share and discuss ideas and topics from coursework in all domains, then the preservice teacher could better connect the theory of what they are learning to the practice of teaching.

## Content of Coursework in Preparation for Teaching Secondary Mathematics

Within a restructured framework for mathematics teacher preparation, coursework must also be reevaluated and restructured to focus more directly and explicitly on the knowledge and skills novice teachers need as they begin the work of teaching. The recommendations that follow outline how the finding of this research informs how courses within each domain should be structured.

### Mathematical Knowledge Coursework

Currently, individuals preparing to become secondary mathematics teachers must take several courses in mathematics to earn licensure. However, the structure of this mathematics coursework needs to be reevaluated to better meet the specific needs of individuals preparing to become teachers, rather than being broad enough to meet the general needs of all course takers. Coursework focusing on mathematical knowledge needs to prepare teachers to know and be able to do mathematics specific for the work of teaching. Teachers not only need to be able to do algorithms correctly, they must also understand how and why the algorithm works. They need to understand how secondary- and college-level mathematical topics are related to elementary topics and to each other. Further, their mathematical understanding must be deep enough that they are able to understand how and why students make errors in their thinking, and they must know multiple ways of thinking about the mathematical topics that they are teaching so that they are able to think flexibly when a student asks a mathematical question.

These types of knowledge are not necessary for most others who use mathematics in their professions, but they are essential for teachers. Hence, courses in this strand should be explicitly designed and delivered to teachers. In other words, general mathematics courses, designed for individuals going in to a variety of fields, do not address or meet these specific educational needs.

Pedagogical Content Knowledge Coursework

Currently, teacher preparation involves courses focusing on "secondary mathematics methods." However, teachers are reporting that they are learning most of their PCK while working in the classroom. Hence, these courses are not meeting the needs of individuals as they enter the field. Coursework in this domain must help prospective teachers understand how best to help students link prior mathematical understandings to new concepts. For example, prospective teachers need to know how to help students use their understanding of addition of whole numbers to understand the addition of algebraic terms, or how to link their understanding of the quadratic formula to finding the vertex or axis of symmetry of a quadratic function. Prospective teachers also need to develop skills in helping students learn to problem-solve and connect concrete understandings to pictorial and abstract understandings. These skills are separate from simply "explaining" mathematics to students, and they involve the ability to impart knowledge to students by linking students to their own understanding of mathematics. Coursework in this domain should facilitate the preservice teachers' transition from expert student of the subject to novice teacher of the subject (Shulman, 1986).

Pedagogical Knowledge Coursework

As with pedagogical content knowledge coursework, there are currently several courses required of prospective teachers that address this domain, but also like PCK courses, PK courses do not appear to be providing adequate preparation for prospective teachers. Cochran-Smith, Davis, and Fries (2003) have noted that the impact of preparing teachers for populations with diverse needs has rendered inconsistent results. However, coursework in this area is vital. Teachers report that they are least prepared in this domain, so much work must be done to help prospective teachers better prepare to work with students of diverse ethnic, cultural, and learning backgrounds. Prospective teachers need to learn how to adapt and modify instruction for all learners. Further, they must learn to motivate and manage students in positive and productive ways.

Curricular Knowledge Coursework

This domain is parallel to compliance domains in other fields. For example, lawyers must know the laws of the nation and the laws of state in which they practice. This is also true of professions such as accountants, contractors, and even hairdressers. Teacher must also be familiar with and comply with relevant local, state, and federal educational policies and laws. For prospective teachers, this means that they should know what it is they are expected to teach within each course and how to assess if they are doing so. For example, prospective teachers need to know if solving quadratic equations is part of the Algebra 1 or the Algebra 2 curriculum expectations for the state within which they teach. Further, teachers should know when and how students learned mathematics curriculum content trajectories at different levels of abstraction. For example, teachers should know when and how students learned to write the equation of a line at different levels of abstraction within each grade level curriculum (in Utah, the concept is first introduced in the sixth grade core curriculum and finally solidified in the Algebra I core curriculum of the Utah State Core Curriculum). Additionally, prospective teachers need to know how to use standardized data to determine what their students know before they enter the classroom, and how well they taught material to students when they were in their classroom. Hence, coursework for prospective teachers needs to include explicit examination of the state and national course expectations, an examination of mathematical trajectories imbedded within state and national mathematics courses, as well as explicit exploration of how to use standardized assessments to inform practice. Coursework in teacher preparation must provide prospective teachers with the knowledge and skills essential to transition from expert student to novice teacher before they enter the classroom. Analysis of the data herein indicates that this is not occurring. Novice teachers are reporting that they gained much of their knowledge and skills for teaching while they were teaching. Hence, these knowledge and skills are "learnable." Teacher preparation must find a way to transfer these learnable knowledge and skills to pre-service teachers during preparation. To do that, I recommend that teacher preparation be structured around the four distinct domains articulated in the conceptual framework presented herein: mathematical knowledge, pedagogical knowledge, pedagogical content knowledge, and curricular knowledge. Coursework within each of the domains must be structured specifically for teachers and the work that they do.

## Recommendations for Licensure

Teacher licensure structures should also be rethought and revised so that only individuals who demonstrate competency in each of the knowledge domains identified by this research become licensed. Current assessment instruments are likely not sufficient. Presently, Praxis exams in content and both general and specific pedagogy are widely used to assess teacher candidates' level of knowledge (NASDTEC, 2000), but there are no exams specifically linked to the curriculum teachers are required to teach. In Utah, teachers are required to pass the Praxis content specific exam (0061 or 0069) and a general pedagogy exam (0523 or 0524) for a Level 1 license in secondary mathematics. It appears clear from the analysis herein, however, that teachers believe they are gaining much of their skills in mathematics and pedagogy (and the other two domains) while they are working with students. Hence, although most mathematics teachers passed the content Praxis exam before commencing teaching (they take the pedagogy exam sometime during the first 3 years of teaching), they are reporting that they gained a significant portion of their mathematical knowledge *while teaching*. Thus, the Praxis exam for mathematical knowledge may not be sufficient in assessing mathematical knowledge for teaching. Licensure standards must assess if teachers have the knowledge and skills they need to teach before they enter the classroom.

Fully licensed teachers have students with higher achievement than those that are not licensed or are on emergency licensures (Darling-Hammond, 2000b; Hawk, Coble, & Swenson, 1985; Fetler, 1999). Licensure policy can help to ensure that preparation programs successfully prepare prospective teachers with the skills and knowledge they need to begin the work of teaching. Assessment of preparedness in each of the domains as part of licensure does not necessarily need to be made through a Praxis exam; however, a uniform metric tool designed specifically to evaluate each of the domains should be a critical part of licensure.

## Future Research

This research begins to clarify how novice teachers view their work and how they perceive their preparedness to do it. Further research needs to focus on better clarifying the distinctions between and overlaps of these domains for novice teachers. Additionally, future research can contribute to understanding how these types of knowledge work together and perhaps develop into the conceptualization of mathematical and pedagogical content knowledge offered in the work of Hill, Ball, and Shilling (2008) and the University of Michigan team for the Learning Mathematics for Teaching (LMT) Project. I suggest that the conceptual framework offered herein should be seen as the building blocks of knowledge needed for teachers as they begin their work and on which the conceptualization of mathematical knowledge for teaching offered by Hill, Ball, and Shilling (2008) and Ball, Thames, and Phelps (2008) stands. By no means does this work seek to refute or diminish that work; rather, it seeks to extend our understanding of the work of mathematics teachers as they begin teaching. I propose that although the four domains of knowledge must be explicitly addressed during preparation and that they offer a means of understanding the work of teachers as they begin their work, that these domains become more interrelated and dependent on one another as the teacher becomes more experienced. How this occurs and what structures facilitate the emergence of the kind of mathematical knowledge for teaching conceptualized by Hill, Ball, and Shilling (2008) and Ball, Thames, and Phelps (2008) should be a topic of future research.

Research is also needed to discover which preparation structures best facilitate development in the four domains of teacher knowledge. Research for this should include data from many perspectives including that of the teacher, objective external assessments such as various Praxis exams, and student achievement data. Additionally, work needs to be done to identify institutions that best prepare candidates to do the work of teaching secondary mathematics and then to identify what structures are in place at those institutions that are different than at institutions that are not as successful.

Last, and probably the most difficult, empirical investigation must be conducted on how mathematical knowledge for teaching at the secondary level is different than mathematical knowledge for other fields. Ball, Hill, and Shilling (2008) have found that identifying mathematical knowledge for teaching at the secondary level has been difficult, and they too have suggested that investigation needs to be done in this area. In order to design coursework to better prepare individuals to teach secondary mathematics, we must first better understand what kind of mathematical knowledge teachers must have to do that effectively.

## Conclusion

This dissertation began with the premise that a vital role of educational policy is to ensure that only those best prepared to do the work of teaching enter the classroom. To that end, the study herein examined novice teacher perspectives of their work in teaching secondary mathematics and the extent to which they felt prepared to do that work. I found that there are four domains of novice teacher knowledge: mathematical knowledge, pedagogical content knowledge, pedagogical knowledge, and curricular knowledge. Though these knowledges are distinct, correlational data indicates that these knowledges are associated with one another. Further, I found that novice teachers believe they are most prepared in the domain of mathematical knowledge and least in the domain of pedagogical knowledge. Data also show that teachers perceive they gain their mathematical and pedagogical knowledges both in college and outside of college, while they perceive that they gain the majority of their pedagogical content and curricular knowledge outside of college. There were no discernable differences in novice teachers' perceptions of preparedness in any of the domains for different Utah institutions.

Based on the results of the research, I have made two recommendations. First, teacher preparation should structure training around each of the four domains in the proposed framework, and coursework in each of the domains should be explicitly designed for the work of teaching secondary mathematics. Second, teacher licensure should be granted based on competency around each of the four domains.

The contribution of this dissertation to research in secondary mathematics teacher preparation is twofold. First, it offers a theoretical framework, supported by empirical evidence discussed in research question 1 that there are indeed four domains of distinct skills and knowledge around which teacher preparation must focus. The conceptual framework advances the research on mathematics teacher preparation by demonstrating that novice teachers must have targeted preparation in each of the four domains. Second, this dissertation contributes empirical evidence that the current structure of secondary mathematics teacher preparation in Utah is leaving teachers not fully prepared to do the work of teaching secondary mathematics when they enter the classroom. The empirical evidence herein reveals that teachers are learning much of their needed skills and knowledge while they are working rather than during their preparation.

Results of this research and consequential recommendations are departures from traditional perspectives of secondary mathematics preparation. Thus, this research is a call to rethink how we both prepare and license individuals to become secondary mathematics teachers. Since the launch of Sputnik, educational policy makers have pushed for change in mathematics education, yet little has changed in how we prepare individuals to become secondary mathematics teachers. This research is evidence that we should change how we prepare these teachers.

# APPENDIX A

# NOVICE SECONDARY MATH TEACHER SURVEY

Part I

Teacher Knowledge Survey

**Directions for Part 1: For each Part 1 survey item listed below, participants are asked to respond to each of two questions, using the response categories provided below.**

Question A: How well prepared are you with respect to the knowledge or skill items listed below?

1) Not at all prepared
2) Somewhat prepared
3) Well prepared
4) Very well prepared

Question B: Where did you PRIMARILY learn each of the knowledge or skills items listed below?

a) in my college ***math*** classes
b) in my college general ***education or licensure*** classes
c) in my college ***math method or pedagogy*** classes
d) during my ***student teaching*** experience
e) from my own ***personal experiences*** (e.g., as a student or tutor)
f) during my initial ***teaching*** experience
g) other; please specify

1. Evaluate the usefulness and appropriateness of mathematics curriculum materials for your students.

2. Help students become self-motivated and self-directed.

3. Use effective verbal and non-verbal communication strategies to guide student learning and behavior.

4. Use a variety of assessments (e.g., observations, portfolios, tests, performance tasks, anecdotal records) to determine student strengths and needs.

5. Maintain discipline and an orderly, purposeful learning environment.

6. Modify instruction, practice, dialog, and assessment for learners who require special education accommodations.

7. Modify curriculum to meet the need of English language learners.

8. Identify and address special learning needs or difficulties.

9. Address the needs of students who receive special education services.

10. Develop and select mathematics curriculum.

11. Use Internet and software for instruction.

12. Use the standards and objects of the Utah State Core Curriculum in selecting curriculum to use for instruction.

13. Use the state's core curriculum and performance standards to plan instruction.

14. Teach mathematical representations, i.e., write variable expressions or equations.

15. Teach connections among mathematical ideas, i.e., identify relationships between algebra and geometry.

16. Take into account students' prior understandings about mathematics when planning curriculum and instruction.

17. Use standardized mathematics assessments to guide your decision about what skills, concepts, and processes to teach.

18. Help students move from concrete understandings of mathematics to abstract understandings, i.e., teach student how to draw pictures of problem situations and then use the picture to write a mathematical expression or equation for the problem.

19. Help students use prior mathematical understandings to build new understandings, i.e., help student connect adding simple fractions to adding algebraic fractions.

20. Help students use comprehension strategies in mathematics to understand problems and make predictions.

21. Analyze student mathematical work to determine what the student understands or does not understand about mathematical concepts.

22. Explain the algorithm of "invert and multiply" for dividing fractions to students both pictorially and numerically.

23. Use problem or tasked based curriculum to develop mathematical understanding.

24. Explain simplification rules such as why $\surd(x+y)^2=(x+y)$ but that $\surd(x^2+y^2)\neq(x+y)$ in a manner that is accessible to secondary students.

25. Explain mathematics symbols in a manner that helps students understand their mathematical meaning, i.e., helping students understand the difference between 2x, $x^2$ and $2^x$.

26. Explain why multiplying two negative numbers renders a positive product.

27. Explain the algorithm for an integral using area.

28. Explain the relationship between area models for multiplication, the standard algorithm for multiplication of multi-digit numbers and the distributive property.

29. Explain why multiplication involving two fractions renders a product smaller than both factors.

30. Prove the quadratic equation.

31. Explain the difference between polynomial and exponential functions.

32. Explain graphing transformation rules (why does f(x-h)+k the graph of f(x) k vertically and h horizontally).

33. Explain why one would want to convert rectangular coordinates to polar coordinates or polar coordinates to rectangular coordinates.

34. Prove fundamental trigonometric identities ($1+\tan^2 x=\sec^2 x$).

## Part II

**Directions for Part II: Indicate the extent to which you agree or disagree with each of the statements below using the following scale.**

1=strongly disagree
2=disagree
3=agree
4=strongly agree

35. If I try hard, I can get through to most difficult or unmotivated students.

36. If a student in my class becomes disruptive and noisy, I feel assured that I know some techniques to redirect him or her quickly.

37. If a student masters a new math concept quickly, this might be because I knew the necessary steps in teaching that concept.

38. Even a teacher with good teaching abilities may not reach many students.

39. When the grades of my students improve it is usually because I found more effective teaching approaches.

40. A teacher is very limited in what she or he can achieve because a student's home environment is a large influence on his or her achievement.

41. I can motivate a student who has low interest in math.

42. If a student did not remember information I gave in a previous lesson, I would know how to increase his or her retention in the next lesson.

43. When a student does better than usual, many times it is because I exerted a little extra effort.

44. English language learners are successful in my class.

45. Some students simply will always struggle with fractions and decimals.

46. Helping all students understand math is harder than I expected.

47. If one of my students could not do a class assignment, I would be able to accurately assess whether the assignment was at the correct level of difficulty.

48. When a student is having difficulty with an assignment, I am usually able to adjust it to his or her level.

49. If students are not disciplined at home, they aren't likely to accept any discipline at school.

50. The hours in my class have little influence on students compared to the influence of their home environment.

51. The amount that a student can learn is primarily related to family background.

52. The influence of a student's home experiences can be overcome by good teaching.

53. If parents would do more with their children, I could do more.

54. How long do you plan to remain in teaching?
__As long as I am able
__Until I am eligible for retirement benefits from this job
__Until I am eligible for retirement from a previous job
__Until I am eligible for Social Security benefits
__Until a specific life event occurs (e.g., parenthood, marriage)
__Until a more desirable job opportunity comes along

__Definitely plan to leave as soon as I can
__Undecided at this time

Part III

**Directions for Part III: In this section, please provide the information requested below so that the researcher can understand the general profile, backgrounds, and teaching responsibilities of the overall respondent group.**

55. How old are you? ____

56. Gender?
    Male
    Female

57. Ethnic Origin: Choose the one that best describes you
    American Indian or Alaskan Native
    Asian
    Black or African American
    Hispanic or Latino
    Native Hawaiian or Pacific Islander
    White
    Race not included above, please specify____

58. From what institution did you earn your undergraduate degree?
    Brigham Young University
    Southern Utah University
    University of Phoenix
    University of Utah
    Utah State University
    Utah Valley State College (University)
    Weber State University
    Western Governors' University
    Westminster College
    Other: Please specify:_____

59. In what year did you earn your undergraduate degree?______

60. From what institution did you earn your secondary teaching licensure?
    Brigham Young University
    Southern Utah University
    University of Phoenix
    University of Utah
    Utah State University
    Utah Valley State College (University)

Weber State University
Western Governors' University
Westminster College
Other: Please specify:_____
I have not yet earned my licensure. Explain:

61. In what year did you earn your license?____

62. What was your college major?
Mathematics
Mathematics Education
Other: please list_______

63. What was your college minor?
Mathematics
Mathematics Education
None
Other: please list______

64. Do you hold a Masters degree?
Yes
No.
If "Yes", what is your degree?

65. How did you earn your teaching license?
As part of my undergraduate degree
After I earned my undergraduate degree
As part of a Masters degree
I do not have a teaching license
Other: please indicate________

66. What level of math endorsement do you hold?
Level 2
Level 3
Level 4
I don't know
None yet. Explain________

67. In what year of teaching are you?
First year
Second year
Third year
Fourth year
Fifth year
Other: Please specify_________

68. Please indicate which (all) grades you are currently teaching (check all that apply).

7th
8th
9th
10th
11th
12th

69. Indicate which class(es) you are currently teaching and how many sections of each class

__Math 7: Number of sections_____
__Pre Algebra: Number of sections_____
__Algebra I: Number of sections_____
__Geometry: Number of sections_____
__Algebra II: Number of sections_____
__Concurrent Enrollment Math (Math 1010, 1050, 1060, etc.): Number of sections_____
__Pre Calculus: Number of sections_____
__AP Math AB: Number of sections_____
__AP Math BC: Number of sections_____
__AP Statistics: Number of sections_____
__Other: Please indicate:

70. In what school district are you currently teaching?

Alpine
Beaver
Box Elder
Cache
Carbon
Daggett
Davis
Duchesne
Emery
Garfield
Grand
Granite
Iron
Jordan
Juab
Kane
Logan
Millard
Morgan
Murray
Nebo
North Sanpete

North Summit
Ogden
Park City
Piute
Provo
Rich
Salt Lake City
San Juan
Sevier
South Sanpete
South Summit
Tintic
Tooele
Uintah
Wasatch
Washington
Wayne
Weber
Charter School
Private School
Other, Please indicate

# APPENDIX B

# MATHEMATICS ENDORSEMENT INFORMATION

# Application for the Utah State Office of Education Mathematics Level 2

This endorsement may be attached to an Educator License with an Elementary, Secondary, or Special Education area of concentration. A person with an Educator License who completes the requirements for the Mathematics Endorsement Level 2 will receive an endorsement allowing them to teach mathematics courses through Algebra.

## Applicant Information

Name________________________________ Date application submitted _______________

CACTUS ID (preferred) ____________________ or SSN ________________________________

District________________________________ School ________________________________

Major ________________________________ Minor ________________________________

Home Address ____________________________________________________________

Home Phone _____________ Work Phone ______________ Email ____________________

**There are two ways to earn the Mathematics Endorsement Level 2**

1. University or college coursework with grades C or better in all required courses
2. Demonstrated competency through National Board Certification

**Instructions for Completing the Application**

1. For university courses, attach original transcripts (internet transcripts are not acceptable), with the courses highlighted.
2. Print the Mathematics Endorsement Checklist and check completed coursework.
3. Send the highlighted transcript and completed checklist with a $40 processing fee to:

For completed endorsements:

Utah State Office of Education
Attn: Janet Strong
Educator Quality & Licensing
250 East 500 South
P.O. Box 144200
Salt Lake City, UT 84114-4200

For State Approved Endorsement Program (SAEP) (paid by district or charter school):

Utah State Office of Education
Attn: Stephanie Ferris
Educator Quality & Licensing
250 East 500 South
P.O. Box 144200
Salt Lake City, UT 84114-4200

Please read the Frequently Asked Questions document on the website for answers to other questions. For specific questions relating to mathematics endorsements contact Diana Suddreth, Secondary Mathematics Specialist, diana.suddreth@schools.utah.gov, (801)538-7794.

**Put a check next to the course that appears on your transcript. Complete the boxes only if "Other" is checked.**

---

**1. Mathematics for Elementary Teachers I**

____**BYU – MathEd 305**
____**SUU – Math 2010**
____**U of U – Math 4010**
____**USU – Math 2010**
____**UVU – Math 2010**
____**WSU – Math 2010**
____***Other-Complete the box at the right***

Name of course ____________________
Date completed ____________ # Hours ____________
University ____________________

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**2. Mathematics for Elementary Teachers II**

____**BYU – MathEd 306**
____**SUU – Math 2020**
____**U of U – Math 4020**
____**USU – Math 2020**
____**UVU – Math 2020**
____**WSU – Math 2020**
____***Other-Complete the box at the right***

Name of course ____________________
Date completed ____________ # Hours ____________
University ____________________

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**3. College Algebra**

____**BYU – Math 110**
____**SUU – Math 1050**
____**U of U – Math 1050**
____**USU – Math 1050**
____**UVU – Math 1050**
____**WSU – Math 1050**
____***Other-Complete the box at the right***

Name of course ____________________
Date completed ____________ # Hours ____________
University ____________________

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**4. Trigonometry**

____**BYU – Math 111**
____**SUU – Math 1060**
____**U of U – Math 1060**
____**USU – Math 1060**
____**UVU – Math 1060**
____**WSU – Math 1060**
____***Other-Complete the box at the right***

Name of course ____________________
Date completed ____________ # Hours ____________
University ____________________

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**Put a check next to the course that appears on your transcript. Complete the boxes only if "Other" is checked.**

---

**5. Probability and Statistics**

____BYU – Math 1040
____SUU – Math 1040 or Math 2040
____U of U – Math 1040
____USU – Math 1040
____UVU – Math 1040
____WSU – Math 1040
____*Other-Complete the box at the right*

Name of course ____________________
Date completed __________ # Hours __________
University ____________________

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**6. Calculus I (Equivalent to Math 1210)**

____BYU – Math 112
____SUU – Math 1210
____U of U – Math 1210
____USU – Math 1210
____UVU – Math 1210
____WSU – Math 1210
____*Other-Complete the box at the right*

Name of course ____________________
Date completed __________ # Hours __________
University ____________________

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**7. Methods of Teaching Middle School or Secondary Math**

____BYU – MathEd 377 & MathEd 378
____SUU – Math 4900
____U of U – Math 4090
____USU – Math 5910
____UVU – Math 3010 & Math 3020
____WSU – MTHE 3010
____*Other-Complete the box at the right*

Name of course ____________________
Date completed __________ # Hours __________
University ____________________

---

**8. Praxis Test**

____0069 OR
____0061

Date Taken ____________________
Score ____________________

---

***A Mathematics Endorsement Level 2 provides authorization to teach the following classes: Basic Math Skills, Math 7, Pre-algebra, and Algebra.***

# Application for the Utah State Office of Education Mathematics Level 3

This endorsement may be attached to an Educator License with an Elementary, Secondary, or Special Education area of concentration. A person with an Educator License who completes the requirements for the Mathematics Endorsement Level 3 will receive an endorsement allowing them to teach mathematics courses through Algebra 2.

## Applicant Information

Name____________________ Date application submitted __________

CACTUS ID (preferred) ______________or SSN ______________

District____________________ School ____________________

Major ____________________ Minor ____________________

Home Address ________________________________________

Home Phone __________ Work Phone __________ Email ______________

**There are two ways to earn the Mathematics Endorsement Level 3**

1. University or college coursework with grades C or better in all required courses
2. Demonstrated competency through National Board Certification

**Instructions for Completing the Application**

4. For university courses, attach original transcripts (internet transcripts are not acceptable), with the courses highlighted
5. Print the Mathematics Endorsement Checklist and check completed coursework.
6. Send the highlighted transcript and completed checklist with a $40 processing fee to:

For completed endorsements:

Utah State Office of Education
Attn: Janet Strong
Educator Quality & Licensing
250 East 500 South
P.O. Box 144200
Salt Lake City, UT 84114-4200

For State Approved Endorsement Program (SAEP) (paid by district or charter school):

Utah State Office of Education
Attn: Stephanie Ferris
Educator Quality & Licensing
250 East 500 South
P.O. Box 144200
Salt Lake City, UT 84114-4200

Please read the Frequently Asked Questions document on the website for answers to other questions.
For specific questions relating to mathematics endorsements contact Diana Suddreth, Secondary Mathematics Specialist, diana.suddreth@schools.utah.gov, (801)538-7794.

**Put a check next to the course that appears on your transcript.** **Complete the boxes only if "Other" is checked.**

**1. College Algebra**

____BYU – Math 110
____SUU – Math 1050
____UMEP – Math 1050
____U of U – Math 1050
____USU – Math 1050
____UVU – Math 1050
____WSU – Math 1050
____*Other-Complete the box at the right*

Name of course ____________________
Date completed ____________ # Hours ____________
University ____________________

**2. Trigonometry**

____BYU – Math 111
____SUU – Math 1060
____UMEP – Math 1060
____U of U – Math 1060
____USU – Math 1060
____UVU – Math 1060
____WSU – Math 1060
____*Other-Complete the box at the right*

Name of course ____________________
Date completed ____________ # Hours ____________
University ____________________

**3. Calculus I**

____BYU – Math 112
____SUU – Math 1210
____UMEP – Math 4910A
____U of U – Math 1210
____USU – Math 1210
____UVU – Math 1210
____WSU – Math 1210
____*Other-Complete the box at the right*

Name of course ____________________
Date completed ____________ # Hours ____________
University ____________________

**4. Calculus II**

____BYU – Math 113
____SUU – Math 1220
____UMEP – Math 4920B
____U of U – Math 1220
____USU – Math 1220
____UVU – Math 1220
____WSU – Math 1220
____*Other-Complete the box at the right*

Name of course ____________________
Date completed ____________ # Hours ____________
University ____________________

**Put a check next to the course that appears on your transcript. Complete the boxes only if "Other" is checked.**

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**5. Foundations of Algebra or Algebraic Structures**

____BYU – Math 190
____SUU – Math 3120
____UMEP – Math 4310
____U of U – Math 4030
____USU – Math 4310
____UVU – Math 3300
____WSU – Math 2110
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

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**6. Euclidian & Non-Euclidian Geometry (Foundations)**

____BYU – Math or MathEd 362
____SUU – Math 3130
____UMEP – Math 3110
____U of U – Math 3100
____USU – Math 3110
____UVU – Math 3100
____WSU – Math 3120
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

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**7. Probability & Statistics (Calculus pre-requisite)**

____BYU – Stat 301
____SUU – Math 3700
____UMEP – Math 5710
____U of U – Math 3070 or Math 5010
____USU – Math 5710
____UVU – Math 4000
____WSU – Math 2410 or Math 3410
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

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**8. Linear Algebra**

____BYU – Math 343
____SUU – Math 2270
____UMEP – Math 4910LD
____U of U – Math 2270
____USU – Math 2270 or Math 2250
____UVU – Math 2270
____WSU – Math 2270
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

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**Put a check next to the course that appears on your transcript. Complete the boxes only if "Other" is checked.**

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**9. Methods of Teaching Secondary Mathematics**

____BYU – MathEd 377 & MathEd 378
____SUU – Math 5910
____UMEP – Math 5910
____U of U – Math 4090
____USU – Math 4500
____UVU – Math 3010 & Math 3020
____WSU – Math 3010
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

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**10. Praxis Test**

____ 0061

Date Taken ____________________
Score ____________________

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***A Mathematics Endorsement Level 3 provides authorization to teach the following classes:***
**Math 7, Pre-algebra, Algebra, Geometry, Algebra 2, Mathematics of Personal Finance, Basic Math Skills, College Prep Math, Quantitative Analysis, and Discrete Mathematics.**

# Application for the Utah State Office of Education Mathematics Level 4

This endorsement may be attached to an Educator License with an Elementary, Secondary, or Special Education area of concentration. A person with an Educator License who completes the requirements for the Mathematics Endorsement Level 4 will receive an endorsement allowing them to teach all secondary mathematics courses.

**Applicant Information**

Name____________________ Date application submitted __________

CACTUS ID (preferred) ______________ or SSN ______________

District____________________ School ____________________

Major ____________________ Minor ____________________

Home Address ________________________________________

Home Phone __________ Work Phone __________ Email ______________

**There are two ways to earn the Mathematics Endorsement Level 4**

1. University or college coursework with grades C or better in all required courses
2. Demonstrated competency through National Board Certification

**Instructions for Completing the Application**

7. For university courses, attach original transcripts (internet transcripts are not acceptable), with the courses highlighted.
8. Print the Mathematics Endorsement Checklist and check completed coursework.
9. Send the highlighted transcript and completed checklist with a $40 processing fee to:

For completed endorsements:

Utah State Office of Education
Attn: Janet Strong
Educator Quality & Licensing
250 East 500 South
P.O. Box 144200
Salt Lake City, UT 84114-4200

For State Approved Endorsement Program (SAEP) (paid by district or charter school):

Utah State Office of Education
Attn: Stephanie Ferris
Educator Quality & Licensing
250 East 500 South
P.O. Box 144200
Salt Lake City, UT 84114-4200

Please read the Frequently Asked Questions document on the website for answers to other questions.
For specific questions relating to mathematics endorsements contact Diana Suddreth, Secondary Mathematics Specialist, diana.suddreth@schools.utah.gov, (801)538-7794.

**Put a check next to the course that appears on your transcript. Complete the boxes only if "Other" is checked.**

---

**1. Calculus I**

____BYU – Math 112
____SUU – Math 1210
____UMEP – Math 4910A
____U of U – Math 1210
____USU – Math 1210
____UVU – Math 1210
____WSU – Math 1210
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

---

**2. Calculus II**

____BYU – Math 113
____SUU – Math 1220
____UMEP – Math 4910B
____U of U – Math 1220
____USU – Math 1220
____UVU – Math 1220
____WSU – Math 1220
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

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**3. Multivariable Calculus**

____BYU – Math 214
____SUU – Math 2210
____UMEP – Math 4910C
____U of U – Math 2210
____USU – Math 2210
____UVU – Math 2210
____WSU – Math 2210
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

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**4. Foundations of Algebra or Algebraic Structures**

____BYU – Math 190
____SUU – Math 3120
____UMEP – Math 4310
____U of U – Math 4030
____USU – Math 4310
____UVU – Math 3300
____WSU – Math 2110
____*Other-Complete the box at the right*

Name of course ____________________
Date completed__________ # Hours__________
University ____________________

**Put a check next to the course that appears on your transcript. Complete the boxes only if "Other" is checked.**

**5. Euclidian and Non-Euclidian Geometry**

____BYU – Math or MathEd 362
____SUU – Math 3130
____UMEP – Math 3110
____U of U – Math 3100
____USU – Math 3110
____UVU – Math 3100
____WSU – Math 3120
____*Other-Complete the box at the right*

Name of course ____________
Date completed ________ # Hours ________
University ____________

**6. Probability and Statistics (Calculus pre-requisite)**

____BYU – Stat 301
____SUU – Math 3700
____UMEP – Math 5710
____U of U – Math 3070 or Math 5010
____USU – Math 5710
____UVU – Math 4000
____WSU – Math 2410 or Math 3410
____*Other-Complete the box at the right*

Name of course ____________
Date completed ________ # Hours ________
University ____________

**7. Linear Algebra**

____BYU – Math 343
____SUU – Math 2270
____UMEP – Math 4910LD
____U of U – Math 2270
____USU – Math 2270 or Math 2250
____UVU – Math 2270
____WSU – Math 2270
____*Other-Complete the box at the right*

Name of course ____________
Date completed ________ # Hours ________
University ____________

**8. Differential Equations**

____BYU – Math 334
____SUU – Math 2280
____UMEP – Math 4910LD
____U of U – Math 2280
____USU – Math 2280 or Math 2250
____UVU – Math 2280
____WSU – Math 2280
____*Other-Complete the box at the right*

Name of course ____________
Date completed ________ # Hours ________
University ____________

**9. Introduction to Analysis OR Advanced Calculus**

____BYU – Math 315
____SUU – Math 4400
____UMEP – Math 4200
____U of U – Math 3210 or Math 3220
____USU – Math 4200 or Math 5210
____UVU – Math 3200
____WSU – Math 4210
____*Other-Complete the box at the right*

Name of course ____________
Date completed ________ # Hours ________
University ____________

**Put a check next to the course that appears on your transcript. Complete the boxes only if "Other" is checked.**

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**10. Number Theory, History of Mathematics OR Capstone Mathematics Course**

____BYU – Math or MathEd 300, Math 387,
Math 350, or Math 355
____SUU – Math 3140
____UMEP – Math 4400
____U of U – Math 3010 or Math 5700
or Math 4400
____USU – Math 4400 or Math 5500 or
Math 5010
____UVU – Math 4340 or Math 3000
____WSU – MTHE 4010 & MTHE 4020
____*Other-Complete the box at the right*

| |
|---|
| Name of course ____________________ |
| Date completed__________ # Hours__________ |
| University ____________________ |

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**11. Methods of Teaching Secondary Mathematics**

____BYU – MathEd 377 & MathED 378
____SUU – Math 4900
____UMEP – Math 5910
____U of U – Math 4090
____USU – Math 4500
____UVU – Math 3010 & Mathe 3020
____WSU – MTHE 3010
____*Other-Complete the box at the right*

| |
|---|
| Name of course ____________________ |
| Date completed__________ # Hours__________ |
| University ____________________ |

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**12. Praxis Test**

____ 0061

| |
|---|
| Date Taken ____________________ |
| Score ____________________ |

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***A Mathematics Endorsement Level 4 provides authorization to teach all secondary Mathematics courses.***

APPENDIX C

INVITATION

Novice Teachers' Perceptions of Secondary Mathematics Teacher

Preparation and Its Correlation to Efficacy

You have been identified as a teacher new to the teaching of mathematics. After reviewing the content of this email, you are invited to click on the link below that will take you to a survey. Should you agree to participate in the survey, you will be asked about your perceptions of your preparation to teach mathematics, your perceptions of your practice, and some demographic information.

The purpose of this research study is to ascertain from novice teachers their perceptions of their secondary mathematics teacher preparation program. The results of this study will be used to inform and improve math teacher preparation and to complete the requirements for the researcher's Ph.D. dissertation.

All information obtained from the survey is submitted anonymously and is entirely confidential. The electronic survey tool (SNAP) protects the anonymity of your responses during the data collection process. Data will be secured and responses coded to ensure confidentiality throughout the data analysis process. All data will be aggregated, so no individual's responses will be available to readers of the research. Participation in the survey is voluntary and submission of your survey responses constitutes informed consent to participate in the research

If you have any questions, concerns, or complaints or if you feel you have been harmed by this research please contact Maggie Cummings, Ph.D. Candidate, Educational Leadership and Policy, University of Utah, 801-573-2811.

Contact the Institutional Review Board (IRB) if you have questions regarding your rights as a research participant. Also, contact the IRB if you have questions, complaints or concerns which you do not feel you can discuss with the investigator. The University of Utah IRB may be reached by phone at (801) 581-3655 or by e-mail at irb@hsc.utah.edu.

It should take 20 minutes to complete the questionnaire. Participation in this study is voluntary. You can choose not to take part and you can also choose not to finish the questionnaire or omit any question you prefer not to answer without penalty or loss of benefits.

By returning this questionnaire, you are giving your consent to participate.

Thank you for your time and effort!

# APPENDIX D

# SPECIFIC ITEMS FROM THE SURVEY THAT COMPOSED EACH CREATED VARIABLE

| Item Number | Item | Original Construct |
|---|---|---|
| 1 | Evaluate the usefulness and appropriateness of mathematics curriculum materials for your students. | CK |
| 2 | Help students become self-motivated and self-directed. | PK |
| 3 | Use effective verbal and non-verbal communication strategies to guide student learning and behavior. | PK |
| 4 | Use a variety of assessments (e.g., observation, portfolios, tests, performance tasks, anecdotal records) to determine student strengths and needs. | PK |
| 5 | Maintain discipline and an orderly, purposeful learning environment. | PK |
| 6 | Modify instruction, practice, dialog, and assessment for learners who require special education accommodations. | PK |
| 7 | Modify curriculum to meet the need of English language learners. | PK |
| 8 | Identify and address special learning needs or difficulties. | PK |
| 9 | Address the needs of students who receive special education services. | PK |
| 10 | Develop and select mathematics curriculum. | CK |
| 11 | Use Internet and software for instruction. | CK |
| 12 | Use the standards and objects of the Utah State Core Curriculum in selecting curriculum to use for instruction. | CK |
| 13 | Use the state's core curriculum and performance standards to plan instruction. | CK |
| 14 | Teach mathematical representations, i.e., write variable expressions or equations. | PCK |
| 15 | Teach connections among mathematical ideas i.e. identify relationships between algebra and geometry | PCK |
| 16 | Take into account students' prior understandings about mathematics when planning curriculum and instruction. | PCK |
| 17 | Use standardized mathematics assessments to guide your decision about what skills, concepts, and processes to teach. | PCK |
| 18 | Help students move from concrete understandings of mathematics to abstract understandings, i.e., teach student how to draw pictures of problem situations and then use the picture to write a mathematical expression or equation for the problem. | PCK |
| 19 | Help students use prior mathematical understandings to build new understandings, i.e., help student connect adding simple fractions to adding algebraic fractions. | PCK |
| 20 | Help students use comprehension strategies in mathematics to understand problems and make predictions. | PK |
| 21 | Analyze student mathematical work to determine what the student understands or does not understand about mathematical concepts. | PCK |
| 22 | Explain the algorithm of "invert and multiply" for dividing fractions to students both pictorially and numerically. | PCK |

| | | |
|---|---|---|
| 23 | Use problem or tasked based curriculum to develop mathematical understanding. | CK |
| 24 | Explain simplification rules such as why $\sqrt{(x+y)^2}=(x+y)$ but that $\sqrt{(x^2+y^2)}\neq(x+y)$ in a manner that is accessible to secondary students. | PCK |
| 25 | Explain mathematics symbols in a manner that helps students understand their mathematical meaning i.e. helping students understand the difference between $2x$, $x^2$ and $2^x$. | PCK |
| 26 | Explain why multiplying two negative numbers renders a positive product. | PCK |
| 27 | Explain the algorithm for an integral using area. | MK |
| 28 | Explain the relationship between area models for multiplication, the standard algorithm for multiplication of multi-digit numbers and the distributive property. | MK |
| 29 | Explain why multiplication involving two fractions renders a product smaller than both factors. | MK |
| 30 | Prove the quadratic equation. | MK |
| 31 | Explain the difference between polynomial and exponential functions. | MK |
| 32 | Explain graphing transformation rules (why does $f(x-h)+k$ move the graph of $f(x)$ k vertically and h horizontally) | MK |
| 33 | Explain why one would want to convert rectangular coordinates to polar coordinates or polar coordinates to rectangular coordinates. | MK |
| 34 | Prove fundamental trigonometric identities ($1+\tan^2x=\sec^2x$). | MK |

# APPENDIX E

# FACTOR ANALYSIS

Rotated Factor Matrix[a]

| | Factor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1. Evaluate the usefulness and appropriateness of mathematics curriculum materials for your students. | .208 | .484 | .397 | .195 | .148 | .224 | -.236 |
| 2. Help students become self-motivated and self-directed. | .027 | .377 | .427 | .020 | .294 | .037 | .493 |
| 3. Use effective verbal and nonverbal communication strategies to guide student learning and behavior. | .125 | .479 | .259 | .035 | .309 | .143 | .102 |
| 4. Use a variety of assessments (e.g., observation, portfolios, tests, performance tasks, anecdotal records) to determine student strengths and needs. | .130 | .171 | .090 | .107 | .520 | .338 | .146 |
| 5. Maintain discipline and an orderly, purposeful learning environment. | .069 | .207 | .263 | .365 | .391 | -.110 | .409 |
| 6. Modify instruction, practice, dialog, and assessment for learners who require special education accommodations. | .193 | .146 | .633 | .084 | .044 | .175 | .164 |
| 7. Modify curriculum to meet the need of English language learners. | .086 | .117 | .465 | .172 | .116 | .149 | .016 |
| 8. Identify and address special learning needs and/or difficulties. | .236 | .270 | .756 | .141 | .104 | .008 | .086 |
| 9. Address the needs of students who receive special education services. | .166 | .179 | .721 | .244 | .155 | .007 | -.084 |
| 10. Develop and select mathematics curriculum. | .368 | .355 | .180 | .418 | .232 | .230 | -.062 |

| | Factor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 11. Use Internet and software for instruction. | .186 | .136 | .251 | .181 | .097 | .423 | -.093 |
| 12. Use the standards and objects of the Utah State Core Curriculum in selecting curriculum to use for instruction. | .217 | .131 | .116 | .845 | .061 | .212 | .030 |
| 13. Use the state's core curriculum and performance standards to plan instruction. | .170 | .168 | .236 | .842 | .048 | .009 | .004 |
| 14. Teach mathematical representations, i.e., write variable expressions or equations. | .266 | .393 | .191 | .103 | .099 | .482 | .034 |
| 15. Teach connections among mathematical ideas, i.e., identify relationships between algebra and geometry. | .585 | .512 | .118 | .159 | .089 | .178 | -.027 |
| 16. Take into account students' prior understandings about mathematics when planning curriculum and instruction. | .186 | .597 | .331 | .217 | .018 | .149 | .029 |
| 17. Use standardized mathematics assessments to guide your decision about what skills, concepts, and processes to teach. | .182 | .329 | .398 | .604 | .125 | .028 | .068 |
| 18. Help students move from concrete understandings of mathematics to abstract understandings, i.e., teach student how to draw pictures of problem situations and then use the picture to write a mathematical expression or equation for the problem. | .342 | .679 | .144 | .241 | .316 | -.011 | -.033 |
| 19. Help students use prior mathematical understandings to build new understandings, i.e., help student connect adding simple fractions to adding algebraic fractions. | .403 | .577 | .269 | .165 | .026 | .229 | .218 |

| | Factor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 20. Help students use comprehension strategies in mathematics to understand problems and make predictions. | .319 | .556 | .204 | .317 | .176 | -.018 | .138 |
| 21. Analyze student mathematical work to determine what the student understands or does not understand about mathematical concepts. | .337 | .153 | .292 | .333 | .186 | .196 | -.271 |
| 22. Explain the algorithm of "invert and multiply" for dividing fractions to students both pictorially and numerically. | .476 | .047 | .218 | .014 | .330 | .229 | -.041 |
| 23. Use problem or tasked based curriculum to develop mathematical understanding. | .268 | .225 | .235 | .112 | .689 | -.022 | -.033 |
| 24. Explain simplification rules such as why Ö(x+y)^2 equals (x+y) but that Ö(x^2+y^2) does NOT equal (x+y) in a manner that is accessible to secondary students. | .772 | .142 | .103 | .224 | .125 | .243 | -.016 |
| 25. Explain mathematical symbols in a manner that helps students understand their mathematical meaning (i.e., function notation or the difference between 2x, x^2 and 2^x) | .755 | .057 | .131 | .218 | -.085 | .192 | .185 |
| 26. Explain why multiplying two negative numbers renders a positive product. | .510 | .091 | .298 | .139 | .173 | .217 | -.074 |
| 27. Explain the algorithm for an integral using area | .709 | .191 | .065 | .040 | .226 | .083 | -.285 |
| 28. Explain the relationship between area models for multiplication, the standard algorithm for multiplication of multi-digit numbers and the distributive property. | .709 | .042 | .243 | .096 | .227 | .109 | -.004 |

| | Factor | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 29. Explain when and why multiplication can render a product smaller than either factor. | .714 | .081 | .150 | .128 | .087 | -.033 | -.012 |
| 30. Prove the quadratic equation. | .747 | .168 | .160 | .112 | .078 | .198 | -.024 |
| 31. Explain the difference between polynomial and exponential functions. | .826 | .204 | .090 | .089 | .152 | .138 | .066 |
| 32. Explain graphing transformation rules (explain why for y=f(x-h)+k, we shift h horizontally). | .753 | .277 | .060 | .133 | .081 | .076 | .175 |
| 33. Explain why one would want to convert rectangular coordinates to polar coordinates or polar coordinates to rectangular coordinates. | .673 | .310 | .043 | .081 | .014 | -.232 | -.160 |
| 34. Prove fundamental trigonometric identities (i.e., the Pythagorean identities). | .804 | .236 | .167 | .105 | -.014 | -.093 | .086 |

Extraction Method: Principal Axis Factoring.
Rotation Method: Varimax with Kaiser Normalization.
[a]Rotation converged in 32 iterations.

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